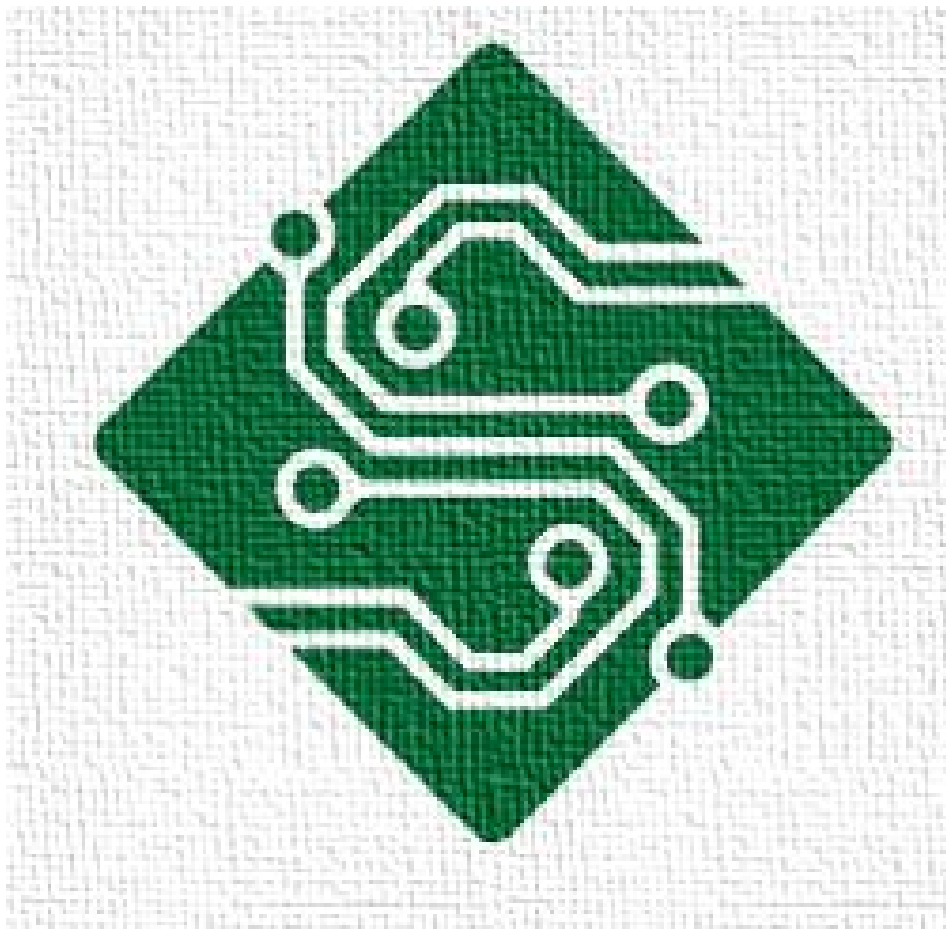


SIGMA LLC, Russia

FastSnap
Digital Electroprospecting System
Version 3.0
User Guide

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2015

Table of Contents

Statement.....	3
Safety Precautions	4
1. General description of FastSnap equipment.....	5
1.1. Configuration and delivery options.....	5
1.2. <i>FastSnap</i> components and markup information	6
1.3. Storage Recommendations	12
1.4. Shipment Recommendations	12
1.5. Safety Precautions.....	12
2. Getting started.....	13
2.1. <i>FastSnap</i> Instruments.....	13
2.1.1. Digital communication line adapter (DLA).....	13
2.1.2. PM-2 receiver unit and attachments	15
2.1.3. CT-2 transmitter unit and attachments	20
2.1.4. CT-2 transmitter unit front panel and control elements.....	24
2.1.5. Current shapeform serial shunt (optional)	32
2.1.6. External active GPS antenna for Rx/Tx unit	33
2.2. Servicing <i>FastSnap</i> instruments	34
2.2.1. Connecting internal battery in receiver unit	34
2.2.2. Connecting internal battery in transmitter unit.....	38
2.2.3. Disconnecting internal batteries in receiver/transmitter units	42
2.3. Getting started: hardware and software	43
2.3.1. Hardware and operating system requirements	43
2.3.2. Installing <i>FastSnap</i> software.....	43
2.3.3. Installing DLA driver.....	50
2.4. Preparation and order of use of <i>FastSnap</i> instrument	51
3. Using <i>FastSnap</i> for TEM surveys.....	52
3.1. Applicability of the TEM method	52
3.2. TEM method: Theory.....	53
3.3. Fundamentals of field TEM surveys	55
3.3.1. TEM systems	55
3.3.2. Choice of sounding configuration.....	57
3.3.3. Off-loop configuration	60

3.4. Phases of work 63

3.4.1 Reconnaissance 63

3.4.2 Survey design 64

3.4.3 Test surveys 64

3.4.4 TEM data acquisition 64

3.4.5 Data interpretation..... 64

Statement

Thank you for purchasing **FastSnap** digital telemetric TEM system.

Before getting started, please read this guide carefully paying special attention to the marks **Note**, **Warning!** or **Precaution!** to ensure stable operation of the system at its best efficiency.

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For the sake of improvement, the manufacturer may change information, specifications, figures, tables, and schematics contained herein at any time without special notice.

Safety Precautions

- 1) Handle the instruments with care during shipment, storage, and use. **DO NOT** throw. When shipping, keep the instruments housed in special boxes or backpacks provided by the manufacturer. Avoid strong vibration.
- 2) Connect all cables, wires, and electrodes to the station units gently, without excess force. In the case of connection problems, check the plugs and sockets for clogging.
- 3) 12 V external power can be used, connected through a supplied lead (usable only with internal batteries installed, even if they are fully discharged).
- 4) Do not plug the input connectors (crocodile clips) of the receiver unit directly to power higher than 5 V (e.g. to transmitter unit terminals or to transmitter loop jumpers at the contact platform) to avoid permanent damage to the receiver.
- 5) Be aware that the transmitter can deliver life-threatening voltage up to 250 V!
- 6) Do not surpass the limits of 250 W full power, 10 A current, and 250 V voltage, i.e. the transmitter current should not exceed 1 A at the input voltage of 250 V (500 W and 20 A with TX power upgrade).

1. General description of FastSnap equipment

FastSnap digital telemeter system is designed for field electromagnetic surveys (mainly TEM). The instruments are supplemented with a program package for a complete TEM survey cycle: a database for data storage and management and tools for survey design, mapping/GPS positioning, recording transient responses, advanced data processing, data visualization and inversion (optional). Other resistivity methods (IP, DC, FI) are supported optionally or partly, i.e. data acquisition is possible but additional external software is required for further processing.

FastSnap is PC-based and cannot be used as a stand-alone system without control of a laptop, pad, or any other portable PC computer, except for some units, such as the transmitter unit.

Surveys with *FastSnap* instruments may have different applications in hydrogeology, engineering geology, petroleum and mineral exploration, etc.

The penetration depth varies with method, loop size, local noise, and local resistivity pattern and can reach 1000 m or more in TEM surveys.

The instruments should only be operated by engineering geophysicists or specially trained personnel, after reading carefully the instructions herein.

This document contains instrument specifications and basic principles of operation and servicing. The observance of rules and recommendations suggested in this manual will provide durable and safe operation of the instruments at best efficiency.

1.1. Configuration and delivery options

There are several main *FastSnap* configuration options (at end user's choice):

- 1) One-channel configuration (one receiver and one transmitter units);
- 2) Two-channel configuration with one transmitter unit (applicable to central-loop TEM surveys and other methods);
- 3) Two-channel configuration with two transmitter units (used for acquiring large amounts of data or as two independent one-channel configurations).

See Table 1 to compare the scopes of delivery for different configuration options.

Table 1. Scopes of delivery for different *FastSnap* configuration options

No	Item	One-channel configuration, number of pieces	Two-channel configuration, one transmitter number of pieces	Two-channel configuration, two transmitters, number of pieces
1	Digital communication line adapter (DLA)	1	1	2
2	USB-AB cable for connecting DLA to PC	1	1	2
3	Cable for connecting DLA to receiver units through digital lines with two inputs/lines	1	1	2

	(streamer)			
4	Short digital line, 50 - 100 m, on an X-shaped reel for coiling/uncoiling and transport	1	2	2
5	Long digital line, up to 500 m, on a metal winch for coiling/uncoiling and transport (optional)	1	2	2
6	<i>FastSnap</i> PM-2 field telemetric receiver unit (Pelicase)	1	2	2
7	Universal cable for connecting to external power	2	3	4
8	Input cable for connecting to the pulse source, <i>Standard ADC</i> input	1	2	2
9	Input cable for connecting to the pulse source, <i>Fast ADC</i> input	1	2	2
10	Cable for connecting digital line to the receiver	1	2	2
11	Receiver loop/line, a 1.5-2.5 mm ² twisted copper wire (optional)	1	2	2
12	<i>FastSnap</i> CT-2 transmitter unit (Pelicase)	1	1	2
13	Short (2 – 2.5 m) control and synchronization cable	1	1	2
14	Long (30 – 50 m) control and synchronization cable	1	1	2
15	Transmitter loop/line, a 2.5 - 6 mm ² twisted copper wire (optional)	1	1	2
16	6V/7.2 Ah internal batteries (optional, not delivered outside Russia)	2	3	4
17	DC batteries (optional, check with distributor if unsure)	-	-	-
18	<i>FastSnap</i> Software	2 keys/license	3 keys/license	4 keys/license






1.2. *FastSnap* components and markup information





See Table 2 for description and photographs of the *FastSnap* main components, attachments, and accessories.





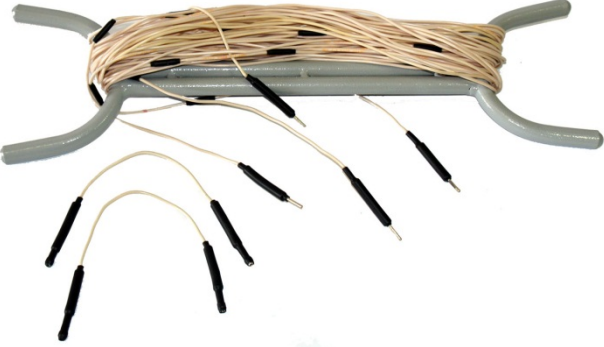
The system consists of several main units (digital line adapter, receiver and transmitter units) and cables. The main units are housed in plastic (Pelican) cases with marked/graved names of the units, sockets, and ports, and unique serial numbers. The cables are marked on connectors (where possible) and on the cables themselves, under the transparent plastic ring. The sockets (ports) of the devices and the respective cables are marked by the color and the same text, as far as possible, using abbreviations.

The devices and cables have high-quality *ODU* and *Schützinger* connectors (where necessary), which provide durable operation with many connection/disconnection cycles.

Table 2. *FastSnap* main components

Components for <i>FastSnap</i> management	
Portable notebook or netbook control computer (PC), with a Windows (XP, Vista, 7, 8) operating system, 32 or 64 bit. To run PC together with the <i>FastSnap</i> station, <i>FastSnap</i> Software should be installed. PC is outside the scope of delivery.	
Digital communication line adapter (DLA) for connecting receiver and transmitter units to PC through digital lines / control cable	
USB – AB cable for connecting DLA to PC	
Cable for connecting DLA to receiver units through digital lines, with two inputs/lines (streamer)	
Short digital communication line, 50 - 100 m, on an X-shaped reel for coiling/uncoiling and transport. The line is a field two-wire twisted pair providing transmission at up to 10 MBit/s.	

<p>Long digital communication line, 400 m, on a metal winch for coiling/uncoiling and transport. The line is a field two-wire twisted pair providing transmission at up to 10 MBit/s.</p>	
<p><i>FastSnap PM-2</i> telemetric receiver unit and accessories</p>	
<p><i>FastSnap PM-2</i> telemetric receiver unit, equipped with two ADC (fast and standard ADC) and a built-in GPS antenna</p>	
<p>Cable for connecting the receiver unit to external power (any 12 V DC power source can be used), marked RxTx EXT PWR Warning! Remember the correct polarity when connecting to an external supply!</p>	
<p>Input cable for connecting the receiver loop/line or any other data source to the <i>Standard ADC</i> input, marked RX STD ADC Warning! Do not plug the input connectors (through the auxiliary crocodile clips) of the receiver unit directly to power higher than 5 V (e.g., 6V or 12V batteries) to avoid permanent damage to the receiver!</p>	

<p>Input cable for connecting the receiver loop/line or any other signal source to the <i>Fast ADC</i> input, marked RX FAST ADC</p> <p>Warning! Do not plug the input connectors (through the auxiliary crocodile clips) of the receiver unit directly to power higher than 5 V (e.g., 6V or 12V batteries) to avoid permanent damage to the receiver!</p>	
<p>Cable-adapter for connecting the current shapeform serial shunt to the Fast/Standard ADC input cable</p>	
<p>Crocodile clips extension for Fast/Standard ADC cable</p>	
<p>Cable for connecting digital communication line to the receiver unit, with a <i>ODU</i> connector on one end and two male/female connectors on the other end, marked RX LINE</p> <p>Warning! Do not connect the line input cable to any external power to avoid permanent damage to the receiver unit.</p>	
<p>Receiver loop/line, 1.5-2.5 mm² twisted copper wire, or any other EM receiver. The loop size may vary from 2×2 to 25×25 m, depending on the task.</p>	

FastSnap CT-2 transmitter unit and accessories

Transmitter unit (current switch), equipped with a built-in GPS antenna.

Warning! Remember the correct polarity when connecting to an external supply! Do not apply power more than 250 V!

Precaution! Be careful when applying power equal or more than 24 V to avoid electric shock accidents!



Cable for connecting transmitter unit to external power (any 12 V DC power source can be used), marked RxTx EXT PWR.

Warning! Remember the correct polarity when connecting to an external supply!



Short (2 – 2.5 m) control and wire synchronization cable for the transmitter unit

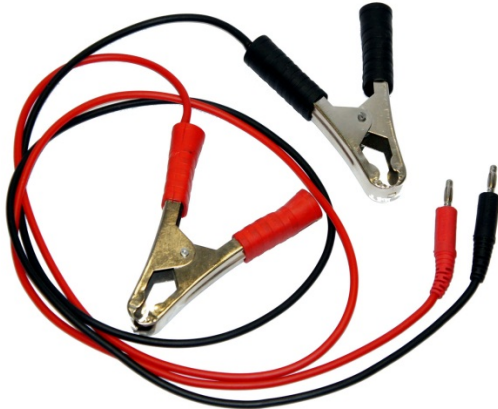







Long (30-50 m) control and wire synchronization cable for the transmitter unit



Transmitter loop/line, a 2.5 - 6 mm² twisted copper wire. The loop size may vary from 20×20 to 200×200m, depending on the task.



<p>Transmitter current source power cable (DC 12-250V)</p>	
<p>Current shapeform serial shunt (R = 0.025 Ohm)</p>	
<p>Supplementary accessories</p>	
<p>Internal batteries for receiver and transmitter electronics. Off-hand AGM batteries, 6V/ 7.2 Ah, size 151×94×34 mm.</p>	
<p>DC power for transmitter (transmitter loop/line): one or several 12-24 V batteries. The use of 12 – 20 Ah (or more) off-hand AGM batteries is recommended. Serial connection of several batteries may be required for larger loop/line sizes in order to achieve the desired output voltage and current.</p>	
<p>External GPS/GLONASS antenna with SMA-M connector for Tx/Rx unit</p>	

AC ~110/220V Tx/Rx unit charger cable	
FastSnap Software	
Program for database management (<i>FastSnap</i> DB), investigation, and survey design	Project Manager 3
Program for managing receivers/transmitter and recording EM responses with arithmetic sampling rate, as well as for express data processing and saving to <i>FastSnap</i> DB	FastEM registration 1.1
Program for advanced processing of data acquired with <i>FastSnap</i> , including filtering random and harmonic noise, stacking (averaging), time conversion, and calculation of informative field transforms for TEM responses	TEM-Processing 1.1
Program for quantitative interpretation of TEM data (modeling/inversion).	Model 3 (Optional)
Program for qualitative interpretation and visualization of acquired data. (Optional)	Profile 3.1 (Optional)

1.3. Storage Recommendations

1. Long storage only indoor, at temperatures from 0 to +40 °C.
2. The indoor air should be free from vapors that may damage insulation or paint coating and cause corrosion to metal (i.e. acids, alkalis, etc.).
3. Do not store the instruments in a damp place.
4. Charge fully the internal batteries before storage. During storing, units should be switched off. Recharge at least every 6 month, otherwise no workability can be guaranteed because of deep discharge.

1.4. Shipment Recommendations

The *FastSnap* instruments are housed in one or several plywood cases, depending on configuration (supplied by the manufacturer) to protect them from physical damage and moisture. For long shipment the use of the original casing is especially recommended.

The coiled wires (digital lines, transmitter and receiver loop/lines) may be transported without special packing, but should be kept dry, clean, and safe from damage to insulation and connectors.

1.5. Safety Precautions

The transmitter, receiver, and adapter units should be protected against dust, dirt, and oxidisation (moisture). Do not immerse the instruments into water. The connectors and cable

jumpers should be kept dry, clean, and safe from external damage. External power should be from 10.5 to 14 V DC voltage.

Take extreme care to use the correct polarity when connecting the receiver and transmitter units to external power. Although the transmitter and receiver internal circuitries are protected from casual polarity reversal on connection to external power, for durable and reliable operation, it is recommended to avoid wrong polarity connections or use of power sources with unsuitable voltage/current.

When powering the instruments from acid batteries, check that voltage is not below 10.5 V and do not turn the batteries upside down during operation.

Note! Handle the *FastSnap* instruments with care during shipment, storage, and use. DO NOT throw. Transport the instruments in special boxes provided by the manufacturer. Avoid strong vibration.

Avoid damage to PC during shipment and operation. Always copy all recorded data to removable disks (external HDD, DVD-R/RW, etc.).

2. Getting started

2.1. *FastSnap* Instruments

2.1.1. Digital communication line adapter (DLA)

FastSnap digital communication line adapter (DLA), shown in Fig. 1, is designed for digital data exchange (transmitting commands and receiving data) between the *FastSnap* receiver units, transmitter and PC, as well as for their synchronization through GPS or cables.



Figure 1. Digital line adapter

The adapter is connected to PC via a 1.1 or later USB (USB port on the back panel), with the delivered cable or another similar USB-AB cable. The PC-DLA data exchange is at 8 Mbit/s.

The adapter has a digital line connector for receiver units (marked DIGITAL LINE) and can support simultaneous operation of two channels (i.e. max. two *FastSnap* receiver units). The data transmission via the digital line interface is at 1 Mbit/s for each channel.

The transmitter connector (marked TX CONTROL) is designed for connecting *control and wire synchronization cable* from the *FastSnap* transmitter for controlling of the transmitter through the special software (*FastEM registration* software). TX CONTROL connector is a noise-protected RS232 (COM) port (based on FTDI chip) combined with hardware synchronization input. Wire synchronization mode can be used if necessary with *FastSnap* transmitter or any other external source, which provides synchronous pulse transmission (i.e. a calibrating generator of special current waveforms).



Figure 2. DLA cable for two channels (streamer)

The adapter kit includes a two-wire (one or two-channel) cable for one (two) digital lines *Streamer/Digital line cable* (Fig. 2). The cable has a DB-9M connector to be connected directly to DLA on its one end and two (one) wires, each with a pair of male/female *Schützing* contacts on the other end, marked CHANNEL 1 and CHANNEL 2.



Figure 3. Short digital line with isolated male/female *Schützing* contacts.

Digital lines (short or long) have isolated male/female contacts on both ends (Fig. 3).

Note! The connection of FastSnap receivers to DLA being polarity sensitive, the receiver units cannot be connected directly to the streamer without digital lines! The male/female contacts of the streamer and digital line cables prevent from polarity reversal. The correct connection is: DLA → Streamer (channel 1 and/or 2) → Digital line → RX LINE cable → FastSnap receiver unit(s).

Note! In the case of one-channel operation, use **channel 1** connection of the digital line and the receiver unit (see marks on the streamer wires).

Note! Wiring diagram of TX CONTROL connector differs from regular RS232 wiring thus cannot be used as regular COM-port without change of wiring (or via adapter). Contact distributor/manufacturer for further information and/or wiring diagram of TX CONTROL connector.

Warning! Install the DLA driver delivered by the manufacturer (as the system will ask), for the adapter to work properly when connected to PC. Select a 32 or 64 bit driver for *Windows*, according to the operating system on your PC. Please see the section *INSTALLING FASTSNAP SOFTWARE* for more details.

Warning! Being that DLA is a composite device consisting of two independent USB devices inside, beside the *FastSnap device driver* the *FTDI USB-to-Serial convertor* device driver has to be installed in order to operate with DLA TX CONTROL port properly. The actual version of FTDI driver is available at <http://www.ftdichip.com/Drivers/D2XX.htm>. Follow the standard installation procedure for Windows, with details coming as part of Windows information.

2.1.2. PM-2 receiver unit and attachments

The *FastSnap* PM-2 telemetric receiver unit (receiver unit hereafter) is designed for recording and digitizing input electric signals and positioning (with a GPS antenna). The received and digitized signals and coordinates are transmitted through digital lines and DLA to a portable PC computer (*FastEM registration* software).

The signals may come from a receiver loop (magnetic dipole), an earthed electric line (electric dipole), or any other electromagnetic sensor that can emit electric signals in the suitable frequency range.

The technical specifications of the receiver unit are listed in Table 3:

Table 3. Specifications of *FastSnap* PM-2 receiver unit

No	Parameter	Value
1	Receiver input / ADC	Two inputs: - Standard ADC: $\Delta \Sigma$ 24 bit; - Fast ADC: direct sampling, 14 bit;
2	Time sampling rate and range (bits are in parentheses)	Fast ADC: 25 ns (14 bit), 100 ns (16 bit), 800 ns (18 bit); 6.4 μ s (22 bit);

		Standard ADC: 25.6 μ s, 204.8 μ s (24 bit);
3	Bandwidth	0.33 Hz to 20 MHz
4	Number of digitized counts per realization (pulse/signal)	14500
5	Recording time range	Fast ADC: 25 ns – 92.8 ms Standard ADC: 25.6 μ s – 2.96 s
6	Maximum input voltage, V	Fast ADC: ± 1 V; Standard ADC: ± 4 V;
7	Input signal gain	Fast ADC: Gain from 1 to 140; max. gain $\times 280$ (specified separately). Standard ADC: Gain factors: 1, 2, 4, 8, 16, 32, 64;
8	Input impedance	Fast ADC: - 5 KOhm (loop); - 2 MOhm (earthed line); Standard ADC: - 2 MOhm (universal);
9	Synchronization system	- no synchronization (serial recording); - GPS synchronization (accuracy ± 90 ns); - external (cable) synchronization (accuracy ± 500 ns);
10	Positioning	- internal <i>Trimble</i> GPS, 12 channels, with built-in or external antenna; - location accuracy (lateral): ± 4 m in 3D (± 8 m in 2D); - location accuracy (height): ± 10 m in 3D;
11	Power and charge	Power supply: - one internal off-hand AGM battery, 6 V / 7.2 Ah (CSB GP-672 or compatible); Internal battery recharge: - built-in 110/220 V charger; - 12 V external power supply, through external power cable (e.g. from a car battery).
12	Data transmission	Digital lines of field two-wire cable (twisted pair), 1 to 400 m.
13	Size and weight	Size: 235 \times 181 \times 104 mm Weight: ~ 3.6 kg (with battery)
14	Operating conditions	Humidity: 80% Temperature: -40 to $+40^{\circ}\text{C}$



Figure 4. *FastSnap* PM-2 Receiver unit

The front panel has five sockets: INPUT, LINE, DC 12V, EXT GPS, AC 110-220 V. The name and serial number of the device and batteries info are likewise shown in the front panel.

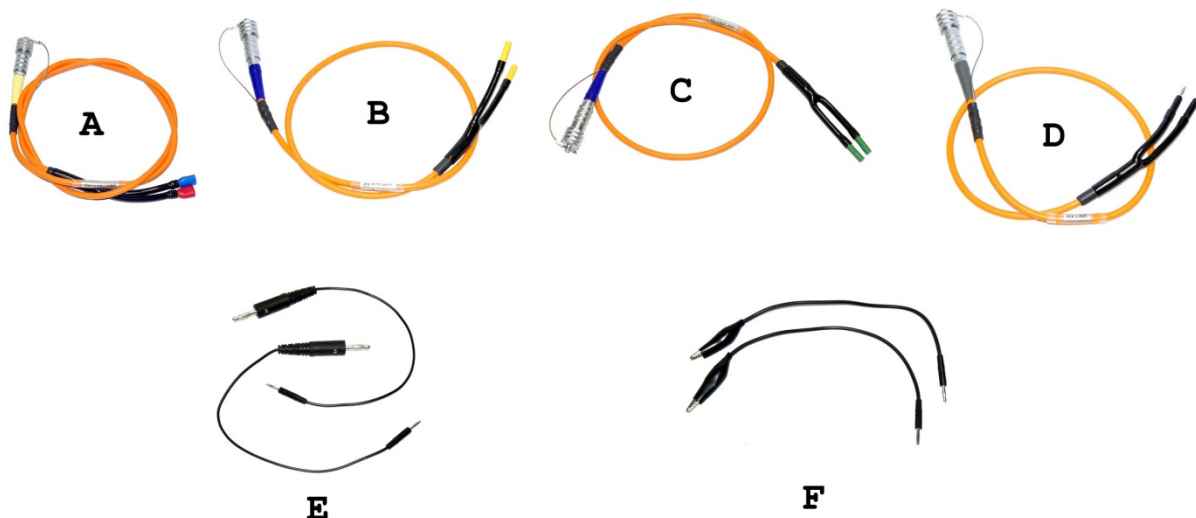


Figure 5. Accessories (cables) for *FastSnap* PM-2 receiver unit. A) External power cable B) Standard ADC cable C) Fast ADC cable, D) Digital line input cable, E) Adapters for connecting of serial shunt F) Crocodile clips extension for Fast / Standard ADC cable

Each receiver unit is supplied with six cables (Fig. 5):

- A. External power cable (marked Rx/Tx EXT PWR). The cable has a *ODU* connector for the DC 12V socket on its one end and two standard insulated jumpers on the other end; the insulation is color coded: red for +12 V and blue or black for -12 V. The jumper size is fitted to the AGM battery of 7 or 12 Ah at 12 V, but may be also connected to other 12 V power sources;
- B. Input cable for Standard ADC (marked RX STD ADC). The cable has a *ODU* connector for the INPUT socket on its one end and two *Schützinger* female connectors (yellow) on the other end, to be connected to a signal source (receiver loop/line takeouts or any other source). The insulation is in a single color to prevent connection to batteries. The highest safe voltage of signals is ± 4 V (for both output and input);
- C. Input cable for Fast ADC (marked RX FAST ADC). The cable has a *ODU* connector for the INPUT socket on its one end and two *Schützinger* female connectors (green) on the other end, to be connected to a signal source (receiver loop/line takeouts or any other source). The insulation is in a single color to prevent connection to batteries. The maximum safe voltage of signals is ± 4 V (output) and ± 1 V (input);
- D. Digital line input cable (marked RX LINE). The cable has a *ODU* connector for the LINE socket on its one end and two male/female *Schützinger* contacts on the other end. The male/female contacts are connected to the respective contacts of the digital wire line (connection directly to the DLA streamer cable contacts will not work without intermediate digital wire line). DO NOT plug the input connectors (male/female contacts) of the receiver unit directly to a 6 V or 12 V battery to avoid permanent damage to the receiver!
- E. Cable-adapters for connecting of serial shunt to Fast / Standard ADC cable. The cables have *Schützinger* connectors from both sides. Big male contact is connected to the respective female connector of the *current shapeform serial shunt* and the smaller one is connected

to the female contact of Fast/ Standard ADC cable. DO NOT plug Fast / Standard ADC input directly to transmitter output socket or directly to the TX loop connectors! For further information about of using *serial shunt* see the “*Serial shunt*” section of the User Guide.

- F. Crocodile clips extension for Fast / Standard ADC cable. The cable has *Schützinger* male connectors from one end for the Fast / Standard ADC female connector and crocodile clip from the other end for connecting to the different sources of signal. Remember that power over 5 V can damage Fast or Standard inputs of the *FastSnap* receiver.

Warning! Do not plug the connectors of the Fast ADC and Standard ADC input cables directly to power higher than 5 V. Even brief connection to power higher than 5 V may cause permanent damage to the receiver unit.

Warning! Make sure to use the correct input cable for Fast or Standard ADC (see the cable marks). Specify properly the ADC type (Fast or Standard) in the *FastEM registration* program, otherwise noise will be recorded instead of signal. Please, see the User Guide of *FastEM registration* software for more details of the ADC choice.

Note! The *FastSnap* receiver unit is a PC-based device. Connection to PC is through a digital line cable and a digital line adapter (DLA). Management is by *FastEM registration* software. Please, see the User Guide of *FastEM registration* software for more details of the data acquisition procedure.

Note! The *FastSnap* receiver unit(s), one- or two-channel, can be used in field or laboratory as a storage oscilloscope. They have a high-speed sensitive input path and can digitize, to a high resolution, and store various electric data, e.g. oscillations in a non-shunted transmitter loop.

2.1.2.1. Turning receiver unit ON/OFF, charging and using of external 12 V power, using of external GPS antenna



Figure 6. Front panel of the FastSnap receiver unit PM-2.

- 1) To turn ON receiver unit please select 'I' position of 3-position switcher (Fig.6, a). There is no light indication in this mode, so do not forget to turn off receiver when out of use.
- 2) To turn OFF receiver unit please select central position of 3-position switcher. In this case all internal electronics will become switched off. Internal battery will be also physically disconnected to avoid it's discharge. Please always turn off receiver unit when out of use.
- 3) Receiver unit has in-built charger. To use it for charging of internal battery please connect AC cable to corresponding socket (Fig. 6, c) and then select CHRG position ('II') of 3-position switcher. The CHRG LED will show current stage of charging process. When LED is constantly lit blue the maximum charging current is being injected into the battery (duration of this stage depends on how deeply the battery is discharged). After the maximum charging voltage is reached, the LED will blink. After the charge is completed CHRG LED will turn off. For full charging of internal battery charger should work for approx. 10 hours.
- 4) During long intensive work with receiver unit, its internal battery may become discharged and unit will turn off. To continue work without charging it is possible to use external 12 V DC power source via special *Rx/Tx EXT PWR* cable connected to DC 12 V socket (Fig. 6, d) and operate with receiver normally, **Note: be careful not to reverse the polarity with external power source!** Also it is possible to use 12 V DC power source to charge battery as described above in 3).
- 5) In conditions of poor GPS signal with in-built antenna it is possible to connect the external active GPS antenna (Fig.6, e) to the appropriate socket (SMA type) and select 'ON' position of respective switcher. This operation can be done with receiver either turned on or off.

2.1.3. CT-2 transmitter unit and attachments

The *FastSnap* CT-2 transmitter unit (transmitter unit hereafter) is designed for switching on and off the load electrical current, commonly at an EM source (transmitter loop or earthed electric line). The current is turned off instantaneously to induce eddy currents propagating through the sampled subsurface (in TEM surveys).



Figure 7. *FastSnap* CT-2 transmitter unit

The transmitter unit is supplied with the following attachments and accessories:

- 1) External power cable (marked Rx/Tx EXT PWR), same as the respective cable for the receiver unit. The cable has a ODU connector for the DC 12V socket on its one end and two standard insulated jumpers on the other end; the insulation is color coded: red for +12 V and blue or black for -12 V. The jumper size is fitted to the AGM battery of 7 or 12 Ah at 12 V, but may be also connected to other 12 V power sources;
- 2) Short (2 – 2.5 m) and long (30 - 40 m) *control & synchronization cables* (marked TX CONTROL, Fig. 8). Each cable has a ODU connector for the CONTROL socket on its one end and one DB9 connector on the other end: for control and synchronization (marked TX CTRL). TX CTRL connector can be connected either to the respective TX CONTROL port of the DLA or to the PC COM port / USB-RS232 adapter (via adapter). Wire synchronization between receivers and transmitter is only possible when TX CTRL connector is connected to the DLA. Short cable is preferable in case of wire synchronization due to better accuracy (less delays for the commands from the DLA).
- 3) Power source cable with big crocodile clips for connection to the power source battery (or several serially connected batteries). This cable has a *Schützinger* male contacts for connecting to the appropriate combined screw clamps / *Schützinger* TX POWER sockets of transmitter. The way of connection is color coded (wires, crocodiles and insulation of the male contacts): red for positive and black for negative polarity. Provided power cable

is not intended for connection to the high voltage power source (over 48 V) – in this case special cable may be required.

- 4) Transmitter loop copper wire (section 2.5 – 6 mm²) – EM field source in TEM surveys. Consist of several pieces (2 – 4, depends on size of loop) to form square shape of TX loop. Each piece is connected to the other via the combined male/female *Schützinger* connectors on each corner of the loop and free ends of loop are connected to the respective TX LOOP socket of the transmitter unit. Any suitable (by electrical resistance and length) wire can be used as the TX loop – in this case wires should be securely connected between pieces and to the combined screw clamps / *Schützinger* TX LOOP socket of the transmitter;
- 5) In-built control panel with OLED display and keypad (see Section 2.1.4.4 TRANSMITTER CONTROL PANEL);
- 6) In conditions of poor GPS signal with in-built antenna it is possible to connect the external active GPS antenna to the appropriate socket (SMA type). Internal or external antenna can be selected through the menu of in-built control panel or by the software (*FastEM* registration program).

See Fig. 9 for the ways of connecting the listed attachments to the transmitter unit.



Figure 8. Control & synchronization cables for *FastSnap* transmitter unit: long and short



Figure 9. *FastSnap* CT-2 transmitter unit attachments: A) TX loop and TX power cable B) Ext 12 V cable and control cable

The technical specifications of the transmitter unit are detailed in Table 4:

Table 4. Specifications of *FastSnap* CT-2 transmitter unit.

No.	Parameter	Value
1	Output voltage	6 to 250 V DC voltage (one or several serial batteries)
2	Output current (transmitter loop)	0.05 - 10 A (optional 20 A with TX power upgrade)
3	Maximum output power	250 W (optional 500 W with TX power upgrade)
4	Time of positive and negative pulses (on-off time), ms	On-Off time: 20, 40, 100, 200, 500, 1000 ms On/Off time ratio: 1:1, 3:1, no pause
5	Support of current periods multiple to industrial noise frequency	Yes, periods multiple to 50 Hz
6	Synchronization system	- GPS synchronization (accuracy ± 90 ns); - external (cable) synchronization (accuracy ± 500 ns);
7	Positioning	- internal <i>Trimble</i> GPS, 12 channels with built-in antenna; - location accuracy (lateral): ± 4 m in 3D (± 8 m in 2D); - location accuracy (height): ± 10 m in 3D;
8	Time of small current (0.5 A) turn-off (ramp speed)** in loops of different sizes, μ s **can vary in a broad range depending on loop size and subsurface parameters	Loops: - 25 \times 25 m: 1 – 2 μ s; - 100 \times 100 m: 4 - 10 μ s;
9	Power and charge	Power supply: - internal off-hand AGM battery, 6 V / 7.2 Ah (CSB GP-672 or compatible); Internal battery recharge: - built-in 110/220 V charger; - 12 V external power supply / recharge, through external power cable (e.g. from a car battery).
10	Management	- PC (software) via DLA TX CONTROL port or RS232 interface (COM port). Control cable can reach 100 m long; - built-in control panel with OLED display and keypad.
11	Size and weight	Size: 37.1 \times 25.8 \times 15.2 cm Weight: ~ 7.2 kg (with battery)
12	Operating conditions	Humidity: 80% Temperature: -40 to $+40^{\circ}\text{C}$

The pulse transmission is in bipolar mode, i.e. positive and negative pulses alternate with pause (current off); in TEM surveys, it is mainly a meander-pause mode. Bipolar transmission without pause (in DC surveys) is supported as well. Different pulse transmission modes are illustrated in Fig. 10; Fig. 11 shows pulse ratios (current on-to-current off).

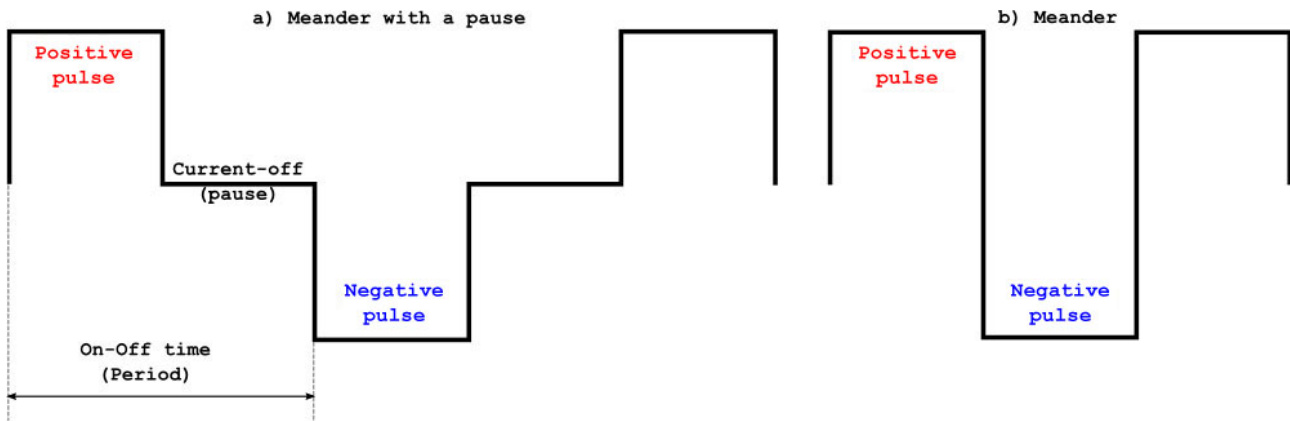


Figure 10. Pulse transmission modes supported by *FastSnap* CT-2 transmitter unit: meander with (a) and without (b) pause

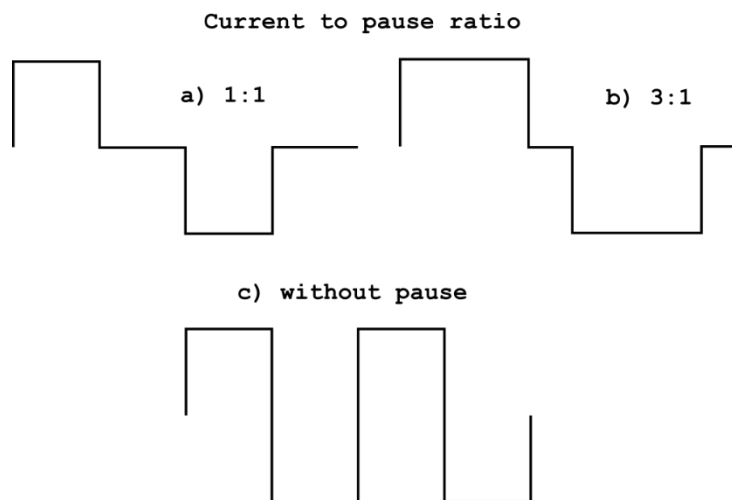


Figure 11. Pulse ratios (current on-to-current off) supported by *FastSnap* CT-2 transmitter unit: 1:1 (a), 3:1 (b), and without pause (c)

For more details of current pulses (time delay, turn-off time (ramp speed), please see the section concerning the transmitter unit and current pulses in User Guide for *FastEM registration* software.

Warning! Although the transmitter unit has reverse polarity protection, avoid wrong polarity connections to power batteries or external power sources to ensure sustainable operation.

Precaution! Do not apply input power more than 250 V to avoid permanent damage to the transmitter unit! Operations with a voltage over 24 V can be dangerous due to risk of electric shock!

2.1.4. CT-2 transmitter unit front panel and control elements

The front panel (Fig.12) of the unit has several sockets (TX LOOP and TX POWER screw clamps, DC 12V, CONTROL, AC 110-220V, GPS) and control panel with OLED display and keyboard.



Fig.12 Front panel of the CT-2 transmitter unit: a) Control panel with OLED display and keypad, b) Connectors section, c) Heat sink of power transistors, d) TX LOOP and TX POWER screw clamps

For review of each element please see the respective part of this manual. Order of turning On/Off Tx unit and its charging see Section “2.1.4.1 Turning transmitter unit On/Off, charging and ...”.

2.1.4.1. Turning transmitter unit ON/OFF, charging and using of external 12 V power

- 1) To turn ON transmitter unit please select ‘I’ position of 3-position switcher (Fig.12, b). OLED display (Fig.12, a) will show model and hardware version / number information for ~4 seconds and then show main menu.
- 2) To turn OFF transmitter unit please select central position of 3-position switcher. In this case all internal electronics will become switched off. Internal battery will be also physically disconnected to avoid it’s discharge. Please always turn off transmitter unit when out of use.
- 3) Transmitter unit has in-built charger. To use it for charging of internal battery please connect AC cable to corresponding 110/220 V socket (Fig. 12, b) and then select CHRG position (‘II’) of 3-position switcher. The CHRG LED will show current stage of charging process. When LED is constantly lit blue the maximum charging current is being injected into the battery (duration of this stage depends on how deeply the battery is discharged). After the maximum charging voltage is reached, the LED will blink. After the charge is completed CHRG LED will turn off. For full charging of internal battery charger should work for approx. 10 hours.
- 4) During long intensive work with transmitter unit its internal battery may become discharged and the unit will turn off. To continue work without charging, it is possible to use external 12 V DC power source via special Rx/Tx EXT PWR cable connected to DC 12 V

socket (Fig. 12, b) and operate with transmitter normally. **Note: be careful not to reverse the polarity with external power source!** Also it is possible to use 12 V DC power source to charge battery as described above in 3).

Note! For proper operation of transmitter unit with external power the internal battery should be connected even in case of full discharge. External power feature will not work if no battery installed inside of transmitter unit.

2.1.4.2. CONTROL and Ext GPS sockets

CONTROL socket is intended to manage transmitter from the PC/laptop through special software *FastEM registration* (for further details of work with transmitter via software see respective section of *FastEM registration* software User Guide). *Control and synchronization cable* (Fig.8) is used to make connection between transmitter (CONTROL socket) and DLA (TX CONTROL socket) or any other PC COM-port. In case of using external (not DLA) COM-port changing of scheme of cable wiring (or special adapter) is necessary (please contact distributor/manufacturer on this matter). Also wire synchronization mode may operate only when *control and synchronization cable* is connected to CONTROL socket of transmitter and TX CONTROL socket of DLA respectively.

Ext GPS socket is intended for connecting of external active GPS antenna (SMA type connector) in case of poor signal quality of internal GPS antenna. Choice between internal or external antenna can be done through the menu (see Section 2.1.4.4 TRANSMITTER CONTROL PANEL) or by software (see *FastEM registration* software User Guide).

2.1.4.3. TX POWER and TX LOOP elements

These elements are designed to connect power source and input load current/EM field source (transmitter loop or line) to the transmitter unit (Fig. 12, d). Each control element is marked correspondingly. Both connectors have combined design (*Schützinger* screw clamps) and either special *Schützinger* male contacts can be plugged into connector or wire can be winded round the pins (Fig. 13).



Figure 13. Combined design of *Schützinger* screw clamps

TX LOOP connection has no polarity. Maximum current of 10 A (20 A with TX power upgrade) can be reached on load with resistance not higher than 2 Ohms. With more resistive load the higher source voltage needed and the lower maximum current can be reached. Need to remember not to exceed of full system power due to risk of damaging internal electronics!

TX POWER wires should be connected with correct polarity (color coded). Only DC power source must be used (i.e. one or several serially connected batteries or rectified AC current)! Maximum allowable voltage is not higher than 250 V and maximum current with this voltage should not exceed value of 1 A, i.e. total system power should be less or equal of 250 W (500 W with 20 A TX power upgrade).

Precaution! Voltage over 24 V could be dangerous due to risk of electric shock.

Warning! Please disconnect crocodile clips from power source before disconnecting of power cable from transmitter unit for safety reason.

Warning! Supplied power source cable is not intended for use with high voltage source (over 48 V).

2.1.4.4. Transmitter control panel

Control panel (Fig. 14), CP hereafter, is an internal part of the *FastSnap* transmitter unit and is designed to manage the autonomous (manual or PC-disconnected) operation of the transmitter unit, control the working parameters, and read the working information (current, voltage, power modules temperature, etc.).



Figure 14. Control panel of *FastSnap* transmitter unit

CP is equipped with a four-line alphanumeric OLED display and a keypad for data input and check. After the transmitter unit is turned on, display shows (~4 s) information about model, hardware number and firmware version (Fig. 12, a). Onwards keypad is used to manage the functions of CP and transmitter unit. The arrows (\uparrow , \downarrow , \leftarrow , \rightarrow) are used to select active menu item and/or change parameters. Selected menu item is checked on the screen with the marker (\blacktriangleright) before the name of item. **ENTER** and **ESC** keys are used to enter/accept or to exit/cancel from the submenu respectively. **STOP** key is intended to send 'stop current' command when current is injected onto the TX load (in case of emergency / erroneous returning from the PC to manual mode it is possible that the transmitter could continue injection of current. It is possible to force stop the current by pressing **STOP** key). **START** key enters 'Work' submenu and starts current when pressed inside of submenu, **GPS** key enters 'GPS' submenu and starts polling of in-built GPS receiver.

CP can operate in two modes: first for working with menu for manual operations with transmitter and second for indicating of basic information (passing and average current, power voltage, temperature of power transistors) while transmitter is connected to PC. Switching between modes can be done via the software command (when control cable is connected) or through the 'SETTINGS' submenu command.

Main menu:

Upper string of main screen is intended to show of GPS status (*GPS=OK* when ready for GPS synchronization and *GPS=NO* if no GPS info is acquired), battery voltage *Bt=XX* (internal or connected to DC 12 V socket) and power source voltage *Pwr=XXX*, connected to TX POWER clamps. When voltage of internal battery becomes low (below 5.5 V) there is blinking text *BATTERY LOW* instead of battery and power voltage information. It is necessary to connect external 12 V battery or charge the internal battery when *BATTERY LOW* indication is on, or working of transmitter can become unstable and transmitter can turn off. Information about voltage is updated approx. every 5 seconds.

Settings submenu: change the operation parameters (\uparrow or \downarrow keys to select item, \leftarrow or \rightarrow to change its value), namely

- **Duty cycle** for changing the pulse ratio; three options are possible: *1:1*, *3:1*, and *NoPause* (without pause);
- **Synchro** for selecting GPS or Wire synchronization (*GPS* or *Wire*);

- **GPS antenna** for selecting of internal or external GPS antenna (*Int* or *Ext*);
- **Off shift** for setting time of the delay after synchronization signal came and before current turn off; three options are possible: *5.6us*, *55.6us*, *1.025ms*;
- **Switch to PC mode** for switching to PC-controlled mode press **ENTER** key (switch back to manual mode can be done by pressing **ESC** key while in PC-mode);

To set the transmitter parameters, first specify the desired values, then press **ENTER** key on any item (except item **Switch to PC mode**). The message *Send parameters OK* on OLED shows that the data has been sent correctly and CP shows **Main menu** screen. To discard any changes of parameters press the **ESC** key – the message *Params were not send* shows that no changes are applied to parameters of transmitter and CP returns back to **Main menu** screen. In case of error of set parameters the display will read *Error sending param. Error code: XX* (CP returns to **Settings**). Error code value can help to understand problem. Should the error occur, return to the **Settings** menu and try all setting and sending steps again. If error still remains, please contact distributor or manufacturer with review of problem and value of error code given by CP.

GPS submenu: shows the status information of GPS receiver in the transmitter unit (updates every second): UTC time (*Time*); GPS synchronization status (*GPS=OK* or *GPS=NO*); number of using satellites (*Sat*); operation mode (*2D* or *3D*); altitude in meters (*Alt=XXXX*); longitude in WGS 84 degrees (*Lon= W/E XXX°XX'X.X"*); latitude in WGS 84 degrees (*Lat= S/N XXX°XX'X.X"*);

Info submenu: checks the transmitter parameters, namely

- **Factory number** for serial number of the transmitter unit;
- **Battery** voltage of power supply from internal (*Int*) and/or external (*Ext*) batteries, voltage of power source (*Pwr*);
- **Temp** for temperatures (Celsius) of current switch (*SW*) and transmitter's interior (*Box*).

Work submenu: for changing of current options and start current:

- **Current mode** (six choices are available: *Low*, *Med_1*, *Med_2*, *Med_3*, *Med_4*, *High*) for adjusting of value of current through the serial connection of powerful resistors to TX load - as the power source DC voltage changes, the current in the transmitter loop/line changes correspondingly;
- **Damping R Ω** (twenty nine predefined values, including *Off* and values in range 50 – 2000 Ohms) - *transmitter loop/parallel shunt* is used to close the transmitter loop across a user-specified resistance in order to eliminate ringing induced by abrupt turnoff. **Damping R Ω** could be switched on only when transmitter load (loop/line) is connected!
- **R_add 0.5 Ω** is used for connection of additional 0.5 Ohm \times 100 W resistor serially with main electric load. It is intended to restrict maximum current in case of

exceeding of maximum value 10 A (20 A for TX power upgrade), e.g. when small size TX loop used;

- **On/Off T(ms)** for setting the on/off time of current pulses (20, 40, 100, 200, 500 and 1000 ms);

Press **START** in the **Work** submenu to start current and press **STOP** to stop it. OLED shows power source voltage, real-time passing and average transmitter current and temperature of power keys and unit's interior. **STOP** can be used to command forced current stop to the transmitter.

Note! A resistor connected serially with the TX POWER input constrains voltage according to the selected **Current mode**:

- 1) *High*: no resistor (0 Ohm), input voltage connected directly to device's output; max. current 10 A (in parentheses – values for 20 A TX);
- 2) *Med_4*: 0.9 Ohm resistor; max. current 9 A (18 A);
- 3) *Med_3*: 1.1 Ohm resistor; max. current 7 A (14 A);
- 4) *Med_2*: 5.2 Ohm resistor; max. current 3 A (6 A);
- 5) *Med_1*: 6.8 Ohm resistor; max. current 2.5 A (5 A);
- 6) *Low*: 22 Ohm resistor; max. current 1.5 A (3 A).

Warning! The actual current in each mode depends on the loop size (length and section size of wires, i.e., the load resistance) and DC voltage. Do not apply current higher than the mode maximum longer than 2 min (no more than 10% higher than indicated for each mode).

Precaution! During the long work of transmitter unit, especially with the medium and large currents, the heat sink (Fig. 12, c) could become hot! Do not touch it with unprotected skin.

Warning! Do not change the Transmitter current during the transmitter cycle, to avoid interfering with the average current and damaging the transmitter's power keys (especially at large current).

Warning! Never start current (especially large) when there is no load connected to TX LOOP contacts and DAMPING RESISTORS is switched on, it could cause permanent damage of selected damping resistor.

Operation:

To manage the transmitter unit with CP:

- Connect all necessary cables to the transmitter unit (transmitter loop or other load to TX LOOP clamps, DC power source to TX POWER clamps, external GPS antenna and TX CONTROL cable (optionally);
- Turn on the transmitter (see section 2.1.4.1 of User Guide);

- Select **Info** item ('select' means select item with arrows keys and press **ENTER**) and check all voltages (or read voltages from *Main menu* screen);
- Select **Settings** item, change all necessary options (*Duty cycle, Synchro, GPS antenna, Off shift*) and send parameters to transmitter with **ENTER** key or discard changes with **ESC**. Make sure that *control and synchronization cable* is connected to the DLA if wire synchronization mode is selected;
- Select **GPS** item and make sure that synchronization status is *GPS=OK* (GPS status is not important if wire synchronization is selected in **Settings** submenu). Positioning of GPS may take some time (up to several minutes) depending on signal quality (better with an external antenna) and usually takes a longer time in the new place far from previous position;
- Select **Work** item (or just press **START** key while in the **GPS** or **Main menu**). Set *Current mode, Damping R Ω , R_add 0.5 Ω , On/Off T(ms)* options and press **START** key. When running GPS synchronization mode and GPS status before starting of current is *GPS=NO*, OLED reads message '*Sync by GPS selected. GPS was not fixed. START to continue. STOP to MAIN MENU*'. Before pressing **START** it is possible to press **GPS** key to check GPS status and then return to **Work** submenu by pressing **START** key again. When current is started OLED shows power source voltage, passing and average current and temperatures of power keys and unit's interior. If some internal error happens during start of current, OLED shows error message with error code which can be useful in order to solve a problem. It is recommended to try starting of current again and only in case of continuous errors contact with distributor / manufacturer on this matter;
- Press **STOP** to stop the current when needed, OLED shows message with average current during last working session. To return to **Work** submenu press **STOP** key again;
- Change the parameters and restart the transmitter using the **Work** submenu if necessary (e.g. to change current or damping resistor value);
- Turn off the transmitter unit when finished.

Warning! When maximum allowable temperature of power keys is reached (≥ 100 C°) transmitter stops the current with message '*High temp IGBT: XXX*'. It is necessary to wait until temperature falls down in order to continue work with transmitter.

Warning! When maximum current value is reached (11 A for 10 A version of transmitter or 22 A for 20 A version) transmitter stops the current with message '*Current is exceeded of XX A. Reduce PWR voltage & try again*'. It is necessary to reduce power voltage or select lower *Current mode* in **Work** submenu.

Saving desired settings of the CP to the FLASH memory:

It is possible to save preferable settings of the CP to the FLASH memory of the transmitter unit. Values of **Settings** and **Work** submenus (except of **Current mode** option) can be stored into the FLASH memory. Before saving please select desired values of parameters in respective

submenus then in the **Main menu** press **ESC** key for approx. 3 seconds. OLED will then display the message 'Save parameters to FLASH as default? Press ENTER to save or ESC to exit. After the saving to FLASH selected parameters will become default parameters and will be loaded automatically after transmitter unit turns on. Rewriting of parameters in FLASH memory is possible at any time when needed.

2.1.5. Current shapeform serial shunt (optional)

Current shapeform serial shunt (Fig. 15) is delivered optionally.



Figure 15. Current shapeform serial shunt (0.025 Ohm)

The CURRENT SHAPEFORM - serial shunt $0.025 \text{ Ohm} \times 100 \text{ W}$, 1% of accuracy, intended for recording of full current pulse waveform and/or current ramp as well as for control of current value using the *FastSnap* receiver unit (see the corresponding section of *FastEM software* User Guide) or any other metering device. The serial shunt has appropriate *Schützinger* male and female connectors to connect it to the transmitter unit and to the TX loop cable accordingly. The receiver unit is connected via the special cable-adapters to the female contacts of the serial shunt and TX loop *Schützinger* connectors. See the Fig. 16 for the scheme of connection of the serial shunt. The serial shunt allows a voltage drop max. 0.5 V at the maximum current of 20 A. When serial shunt is not used it should be disconnected from the transmitter unit in order to avoid decreasing of maximum current.

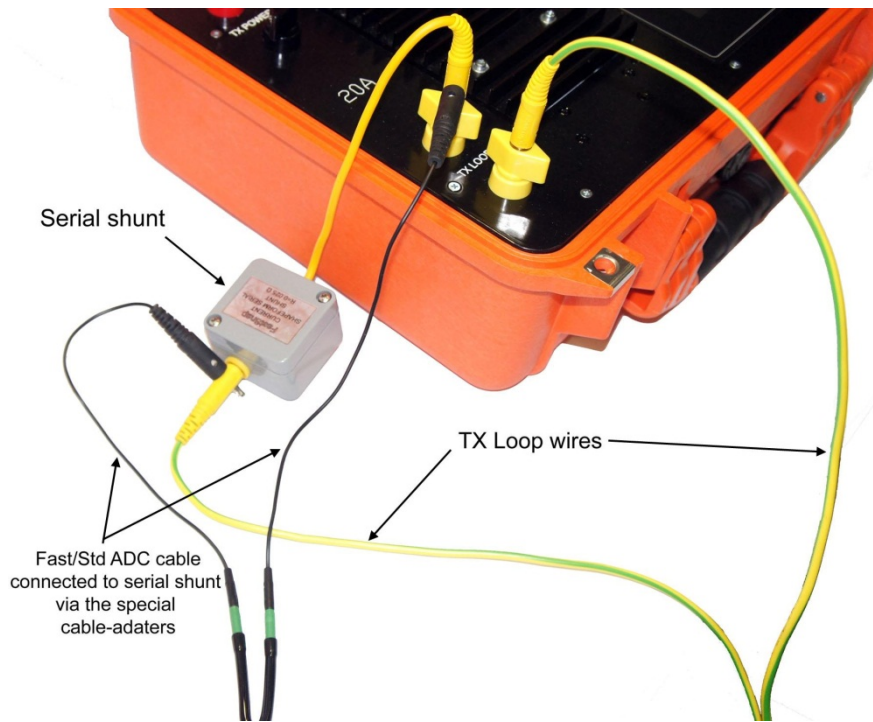


Figure 16. Way of connection of the serial shunt

2.1.6. External active GPS antenna for Rx/Tx unit

The *FastSnap* units utilize universal external active GPS antennas.



Figure 17. Active GPS antenna for Rx/Tx unit with SMA-M connector.

GPS antenna should be connected by the same way both for receiver and transmitter units using GPS SMA socket on the front panel of devices (Fig. 18).

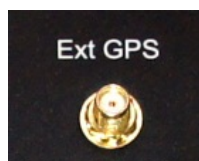


Figure 18. GPS SMA socket on the front panel of receiver and transmitter unit.

2.2. Servicing *FastSnap* instruments

The servicing recommendations below are relevant either to the first run of the station after purchase (or long storage) or to preparation for long storage when internal battery will stay disconnected.

Note! Remember to charge internal battery of units after long storage or after installation of the new battery.

2.2.1. Connecting internal battery in receiver unit

Connecting internal battery in the *FastSnap* receiver unit may be necessary after purchase or long shipment, or storage for a long time.



The internal battery in the *FastSnap* receiver unit is one 6 V/7.2 A·h off-hand AGM battery (e.g. CSB GP 672 battery or compatible).

The connection procedure requires special care. Please, follow the guide below and refer to the figures. A medium crosshead screwdriver will be needed.



1) Unscrew and remove the lid (ten cross screws on the corners and in the middle, including those that connect the connector cap wires to the lid).



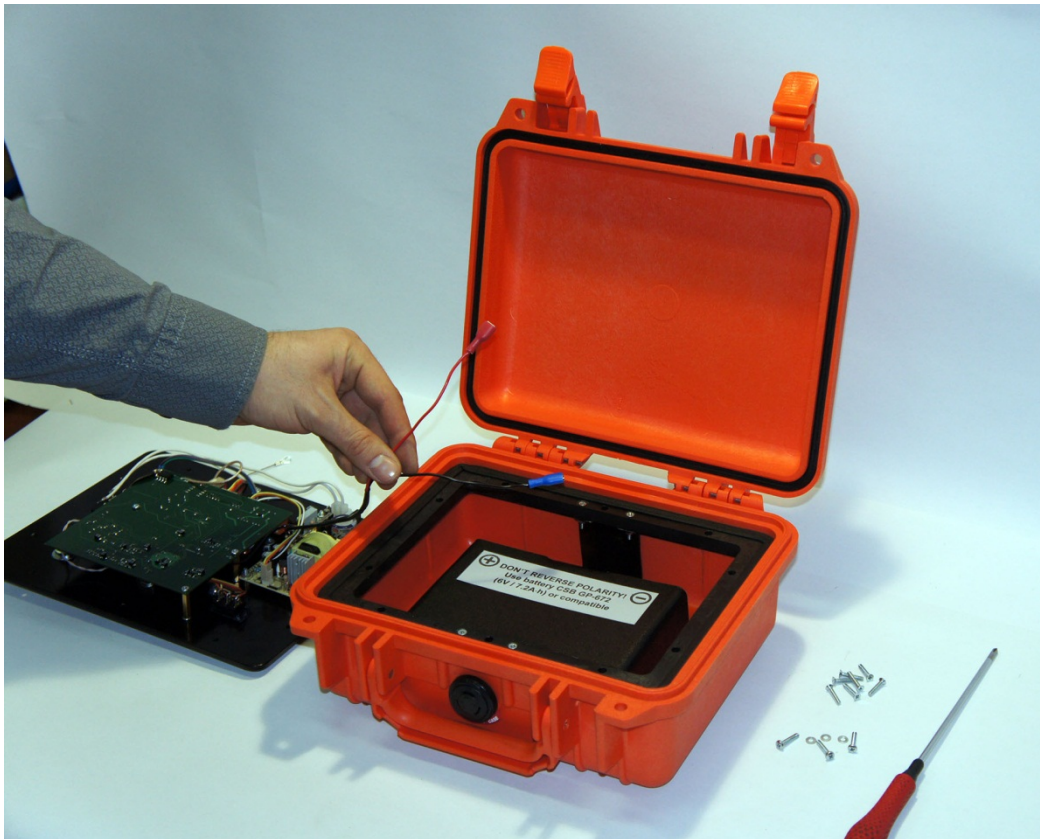
2) Remove the lid gently. A rubber gasket on the case is used to protect the device from dust and moisture. Be careful not to damage the casing or lid paint!



3) Unscrew plastic battery cover (two cross screws). The device is ready for battery connection.



4) Insert battery under the plastic cover with the correct polarity checked on the cover.



5) Connect power wires from PCB to the battery making sure the polarity is correct (red for positive and blue or black for negative). Fix plastic cover and battery with the screws gently.



6) Check unit for proper operating. Connect AC 110/220 V or Ext 12 V cable (and 12 V battery accordingly) to receiver unit and set 3-position switcher to CHRG position, blue LED should light on. Turn off unit by set central (OFF) position of 3-position switcher.



7) Before fixing the lid, check that the rubber gasket is set well in its groove and battery is well placed inside of unit. Insert ten screws and screw the lid without excess force. The fastened lid should closely fit the casing, without any skew or gaps. The device is ready for further operation!

2.2.2. Connecting internal battery in transmitter unit

Connecting internal battery in the *FastSnap* transmitter unit almost the same to such procedure for the receiver unit.

The internal battery in the *FastSnap* transmitter unit is same to battery of receiver unit (6 V/7.2 A·h).

The connection procedure requires special care. Please follow the guide below and refer to the figures. A medium crosshead screwdriver will be needed.



1) Unscrew and remove the lid (ten cross screws on the corners and in the middle including those that connect the connector cap wires to the lid).



2) Remove the lid gently. A rubber gasket on the case is used to protect the device from dust and moisture. Be careful not to damage the casing or lid paint!



3) Unscrew plastic battery cover (two cross screws). The device is ready for battery connection.



4) Insert battery under the plastic cover with the correct polarity checked on the cover.



5) Connect power wires from PCB to the battery making sure the polarity is correct (red for positive and blue or black for negative). Fix plastic cover and battery with the screws gently.



6) Check unit for proper operating. Set 3-position switcher to ON position, LCD display should initiate. Turn off unit by set central (OFF) position of 3-position switcher.



7) Before fixing the lid, check that the rubber gasket is set well in its groove and battery is well placed inside of unit. Insert ten screws and screw the lid without excess force. The fastened lid should closely fit the casing, without any skew or gaps. The device is ready for further operation!

2.2.3. Disconnecting internal batteries in receiver/transmitter units

Disconnecting internal batteries in the *FastSnap* receiver/transmitter units may be necessary before long transport or storage (longer than 6 month). Before storage or shipment, recharge the batteries with the in-built charger.

The procedure of opening the box is generally the same as that for connecting batteries (section [2.2.1](#) and [2.2.2](#)). Once the box is open, release the batteries from the fastening clamps. The batteries may stay inside the box during storage but should be taken out for shipment, especially to long distances by land or by air. Keeping outside the box prevents the batteries from causing damage to the internal elements of units during vibration or overpressure.

Fasten all screws in their places after disconnecting and taking out the battery so as not to lose the parts.

2.3. Getting started: hardware and software

2.3.1. Hardware and operating system requirements

It is recommended that the portable PC computers to be run in the field were dust- and water-proof, but ordinary consumer laptops (notebook or netbook) can be used as well provided that special care is taken to avoid dust and excess moisture. Main hardware and system requirements are listed in Table 5:

Table 5. Hardware and system requirements

Operating system	MS Windows XP, Vista, 7, 8. Both 32 and 64 bit versions are supported
RAM	Min. 1 Gb, recommended 4 Gb or higher
Processor clock speed	x86 Intel or AMD 1 GHz or higher
Display	High-clear, not darkening in the sun, Screen resolution min. 1024×768 , recommended 1600×900
Hard disk	HDD or SSD, min. 60 Gb
Number of USB ports	min. 1

Mouse is recommended as a convenient pointing device. At least one USB port is required for connecting a digital line adapter.

High-performance laptops or desktop workstations are recommended for TEM data processing and interpretation with *FastSnap* software. The programs of the package have been designed bearing in mind the existing advanced processor facilities and multithread processing and inversion procedures.

2.3.2. Installing *FastSnap* software

FastSnap Software is supplied on a CD (or USB flash drive) together with the *FastSnap* instruments. The programs of the package are protected from unauthorized use with *Sentinel HASP HL* hardware keys. The number of keys (licenses) provided to end users depends on configuration (Table 1).

The software is installed with the *setup.exe* program from CD or a local copy of the *FastSnap* distribution kit.

The programs in the delivered distribution kit may vary depending on configuration and client-specific choice of software options. Below there is a list of typical kit components:

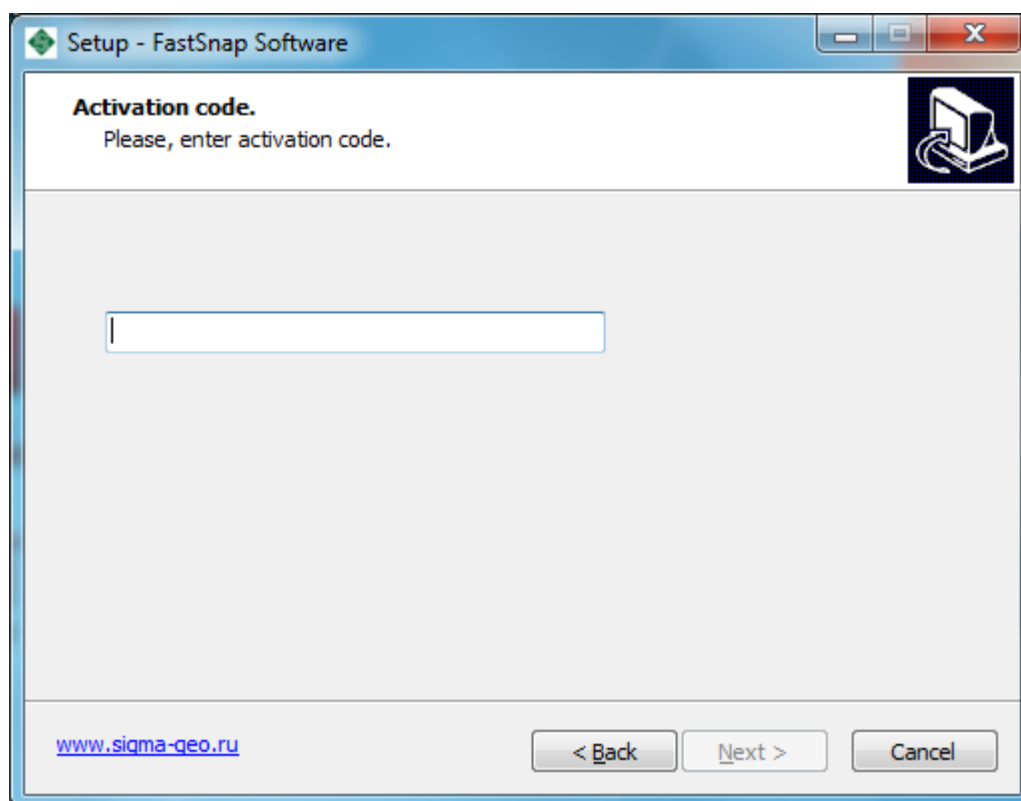
- 1) *Project Manager*: database manager and integrated GIS;
- 2) *FastEM registration*, including an *OAMDrv* command driver, a program for managing the gauge and EM data acquisition;
- 3) *TEM-Processing*: a program for processing/filtering the acquired data (designed especially for TEM and IP data);
- 4) *Model 3* (optional): a program for modeling and inversion of TEM data;

- 5) *Profile 3* (optional): a program for qualitative interpretation and visualization of data;
- 6) *Update Client*: a program for downloading program updates through a local network or internet;
- 7) *FastSnap Database*, including the DB structure and processing & interpretation trials (optional);
- 8) Drivers for HASP hardware keys and a DLA driver.

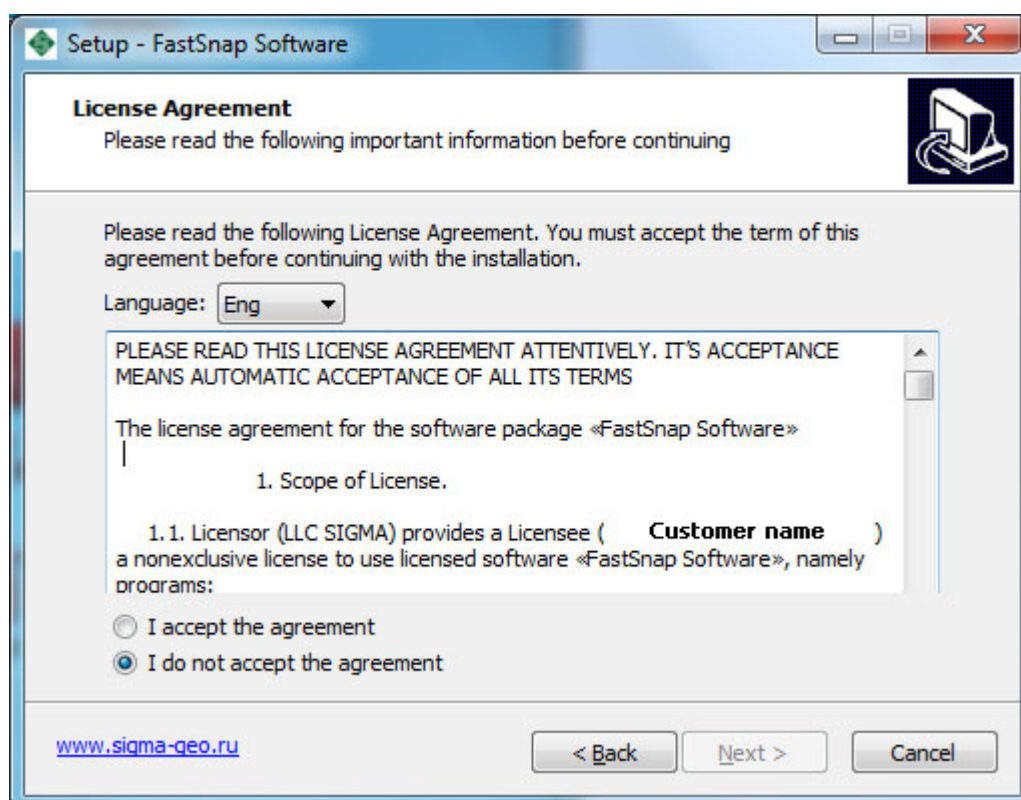
Generally, it is a standard *Windows* setup procedure, which does not require any additional operations. Below there is an example setup wizard for Windows 7:



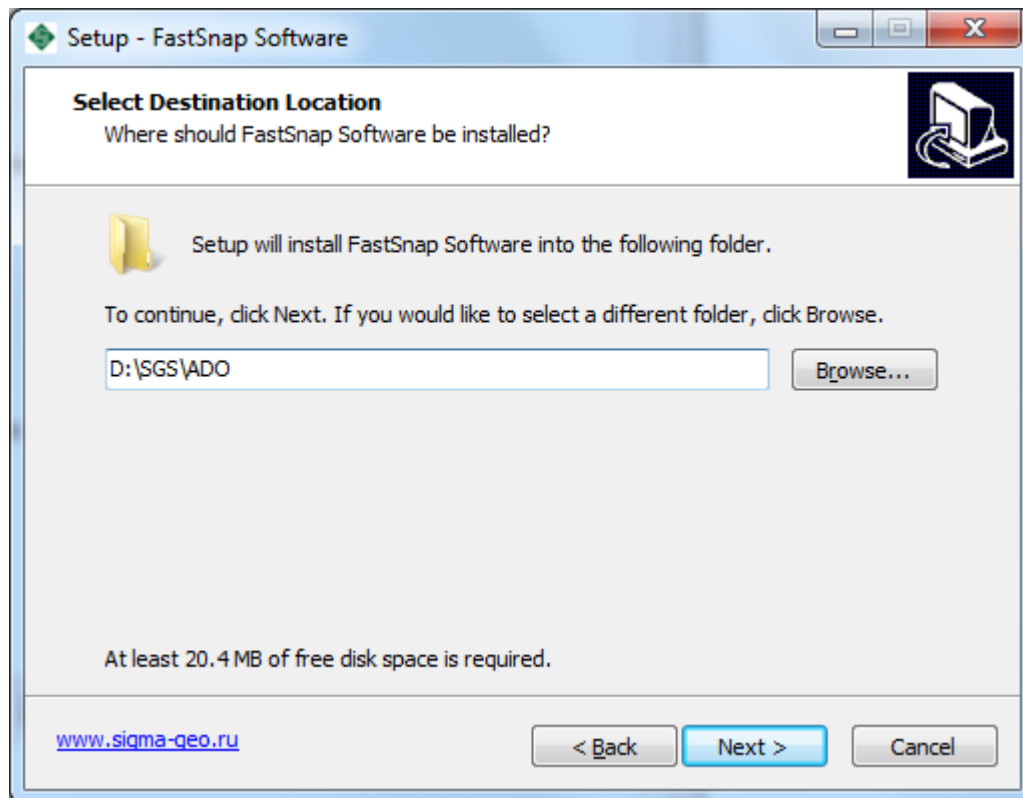
1) The setup starting screen (Screen 1). Click *Next* to continue the installation.



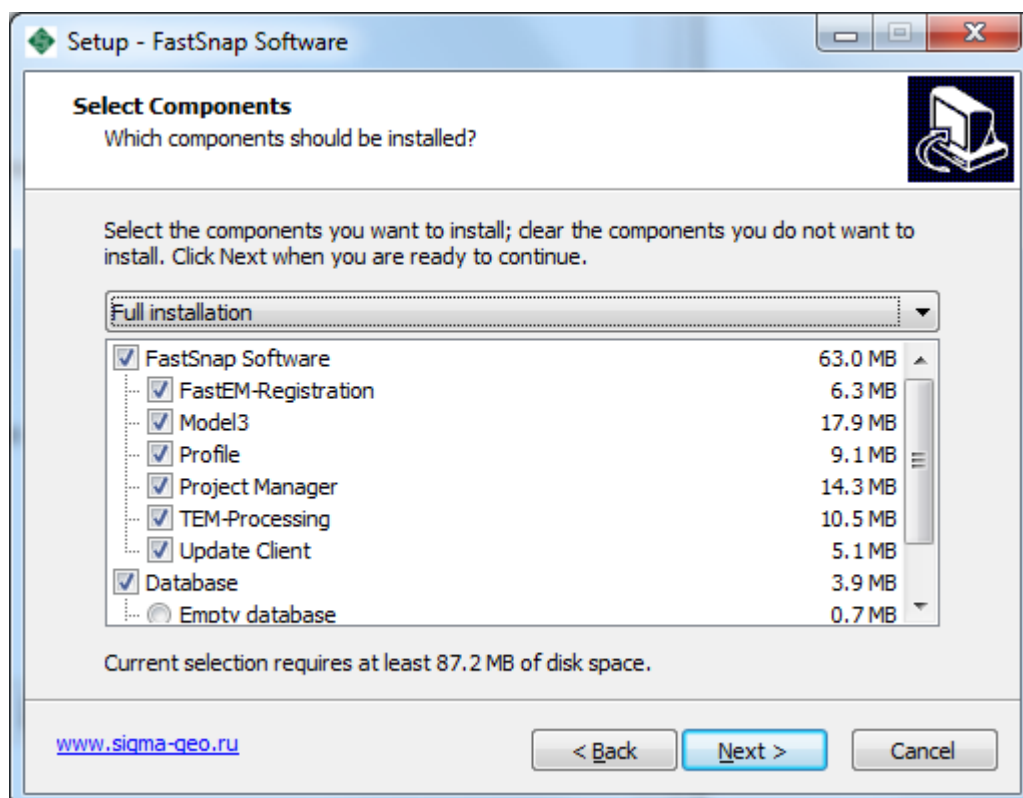
2) Screen 2: software activation dialog, where to type the activation code supplied together with the software.



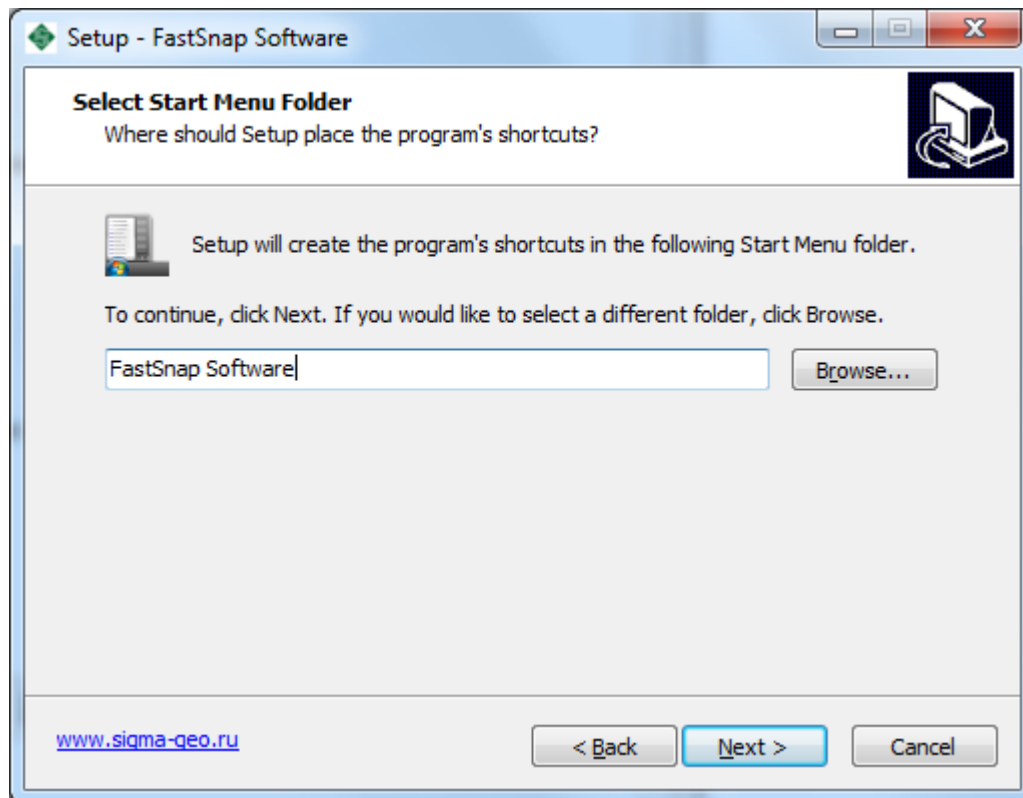
3) Screen 3: license agreement, with a language choice (Russian or English). Select *I accept the agreement* and click *Next* to continue setup if you agree with all license conditions, or select the other option and stop otherwise.



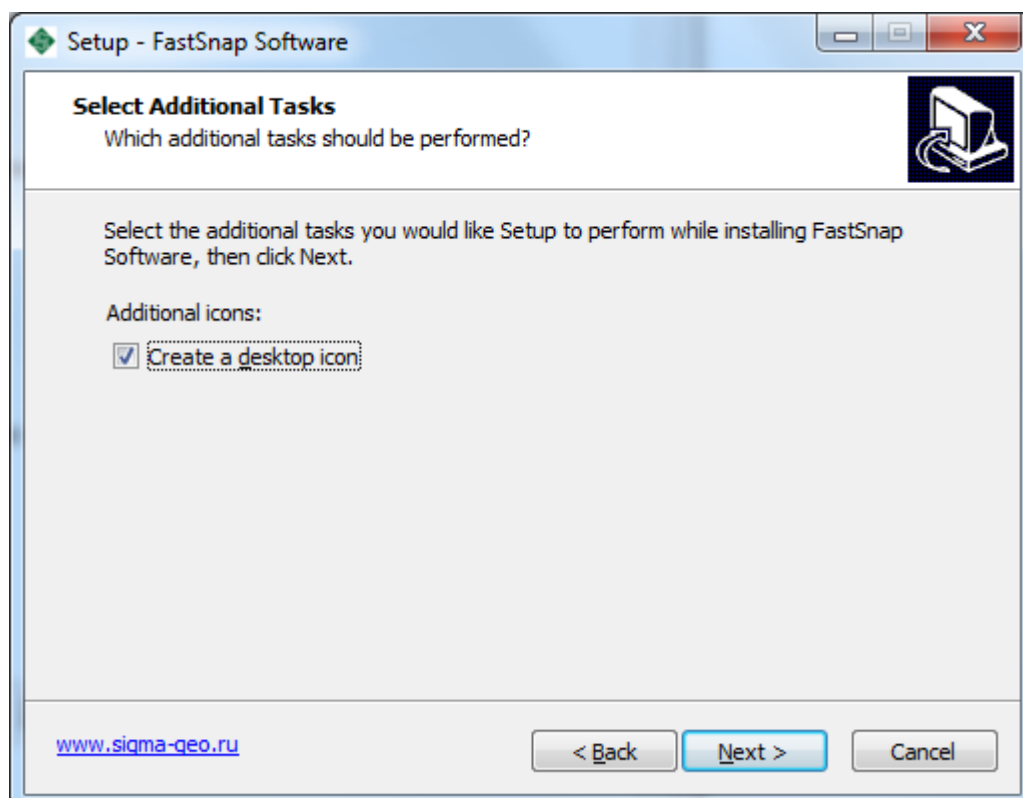
4) Screen 4: setup folder choice. A standard setup path (D:\SGS\ADO) is suggested by default but the user may select any other folder.



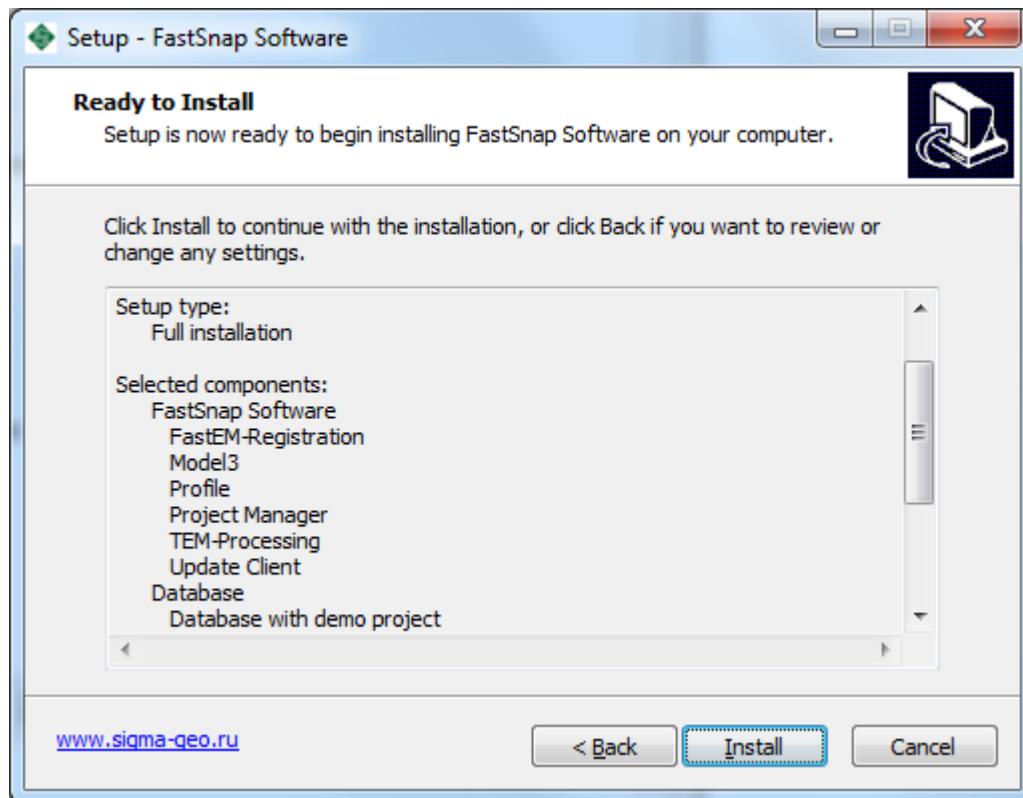
5) Screen 5: choice of setup components. The options include the programs to be installed, the options of database setup (*do not install, empty DB, trial DB*), and help files.



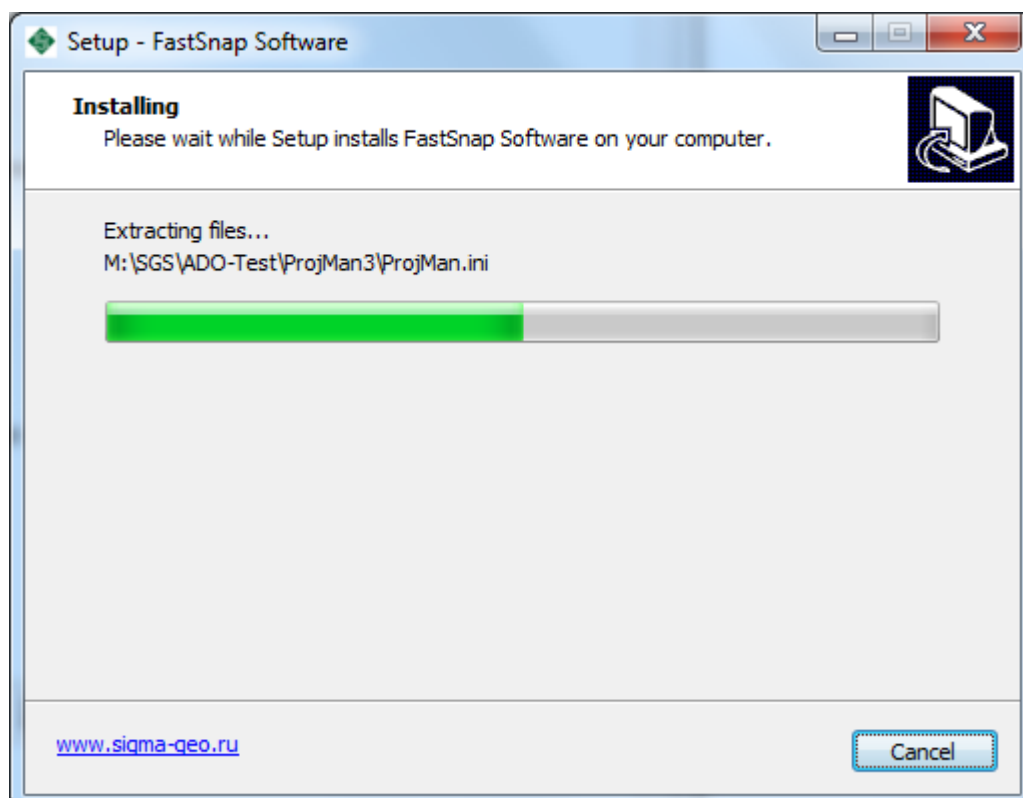
6) Screen 6: choice of folder name among *Programs* in Windows Start Menu.



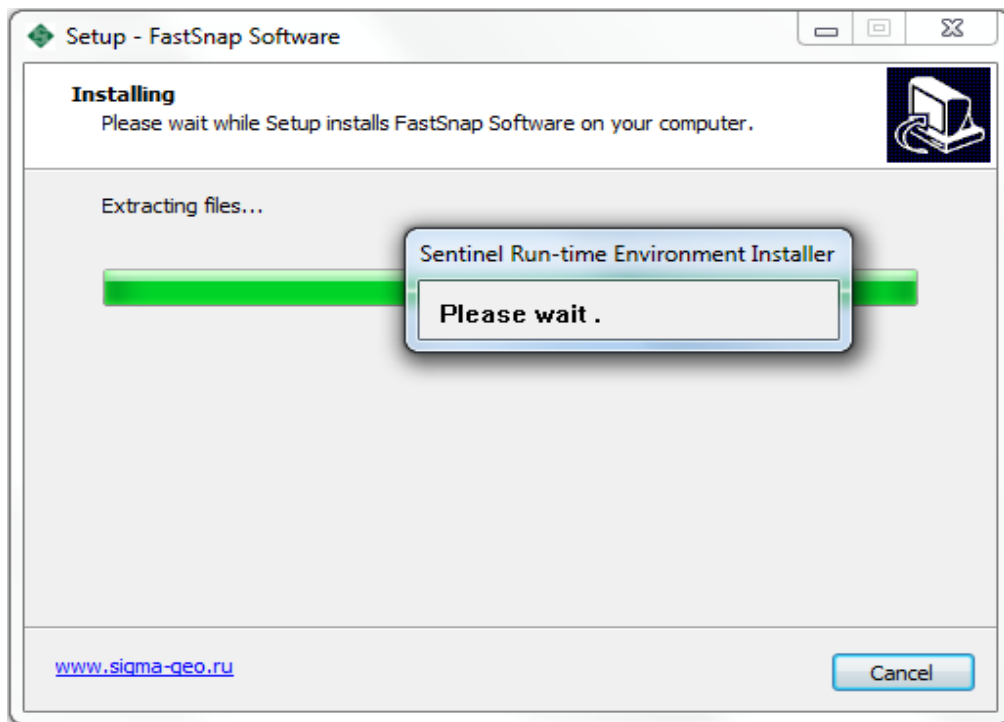
7) Screen 7: creating desktop icons of the selected programs.



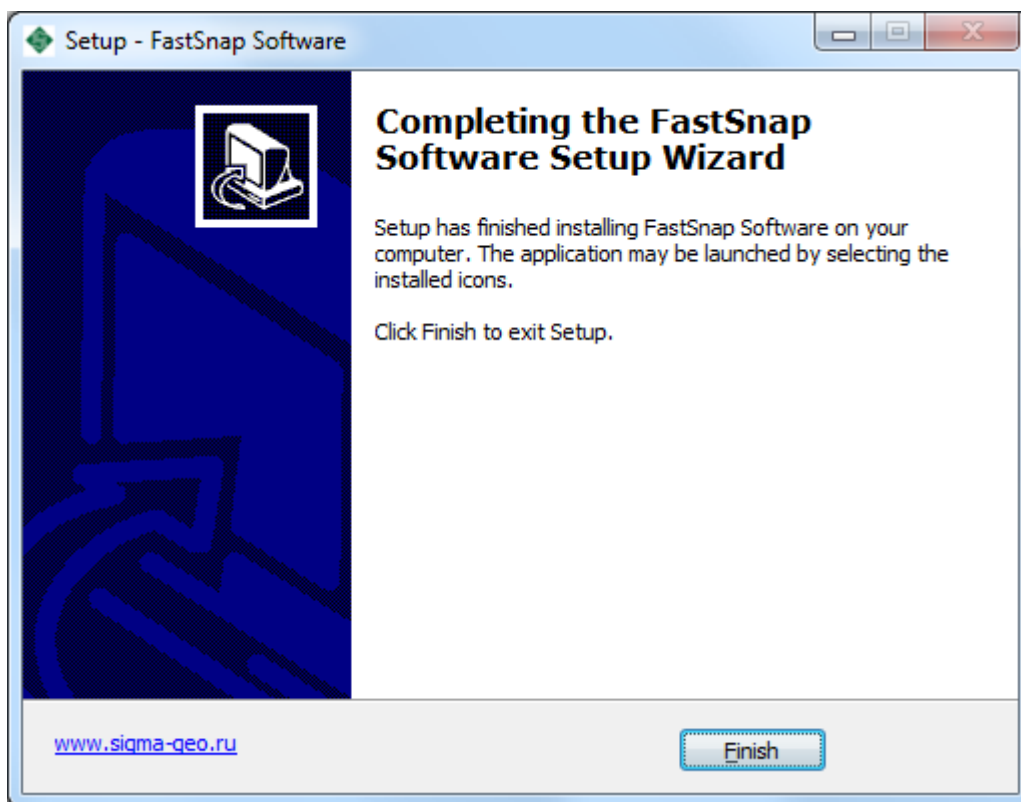
8) Screen 8: displaying all information about the selected settings before the installation begins.



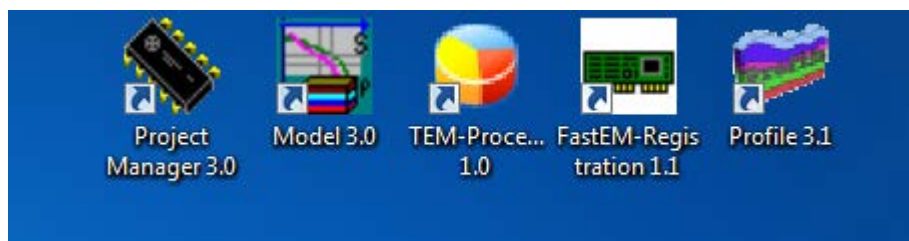
9) Screen 9: Copying files to the selected disk directory.



10) Screen 10: installing Sentinel HASP hardware keys. The program may show a message of installation failure if the driver has been already installed in the system. This is not an error and does not interfere with further use of the programs. If the very first setup fails, download a new driver version available at <http://sentinelcustomer.safenet-inc.com/sentineldownloads/>



11) Screen 11: message of successful setup completion. The *FastSnap* programs are ready to work and may be launched from the Start Menu or by selecting the respective desktop icons.

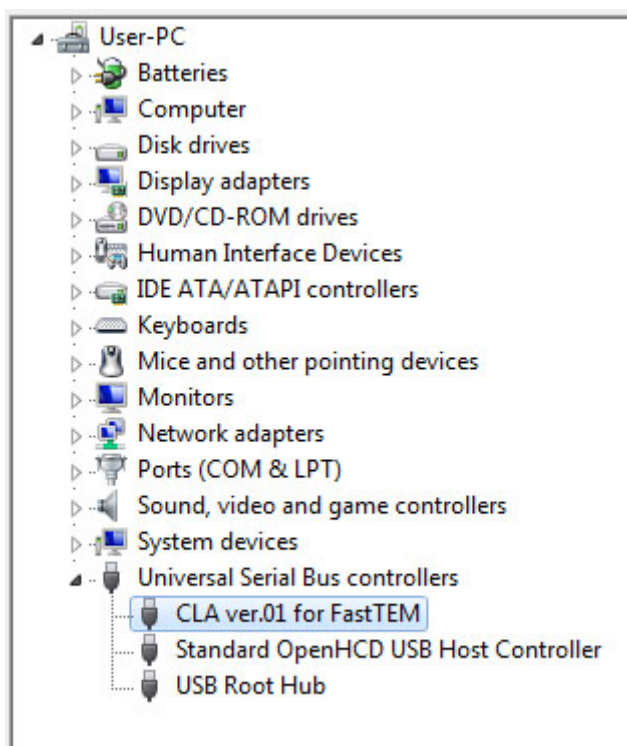


12) Desktop icons of the *FastSnap* programs.

2.3.3. Installing DLA driver

It is recommended to install the original DLA driver delivered by the manufacturer to ensure that the adapter run properly together with *FastEM registration* program. Once *FastSnap* software has been installed, the DLA driver can be found at D:\SGS\ADO\DrvUSB (for the default setup). During software setup DLA drivers will be installed automatically, but if necessary it is possible to install/reinstall it manually.

To install DLA drivers manually please go to the “32\FastSnap\” or “64\FastSnap” subfolder (depends on 32 or 64-bits version of Windows) of driver’s path and run “SGS_CLA_Fast_Snap_Driver_XX_bit.msi” setup package file. Standard setup dialog will appear.



After the device driver has installed successfully, the device (CLA ver.01 for FastTEM) can be found among *USB Controllers* in the *Device Manager* menu (if DLA is connected to PC via USB cable). After the driver installation, DLA can be used with *FastEM registration* program. Please see the respective User Guide for more details of using *FastEM registration*.

2.4. Preparation and order of use of *FastSnap* instrument

For general connection scheme please refer to Figure 19.

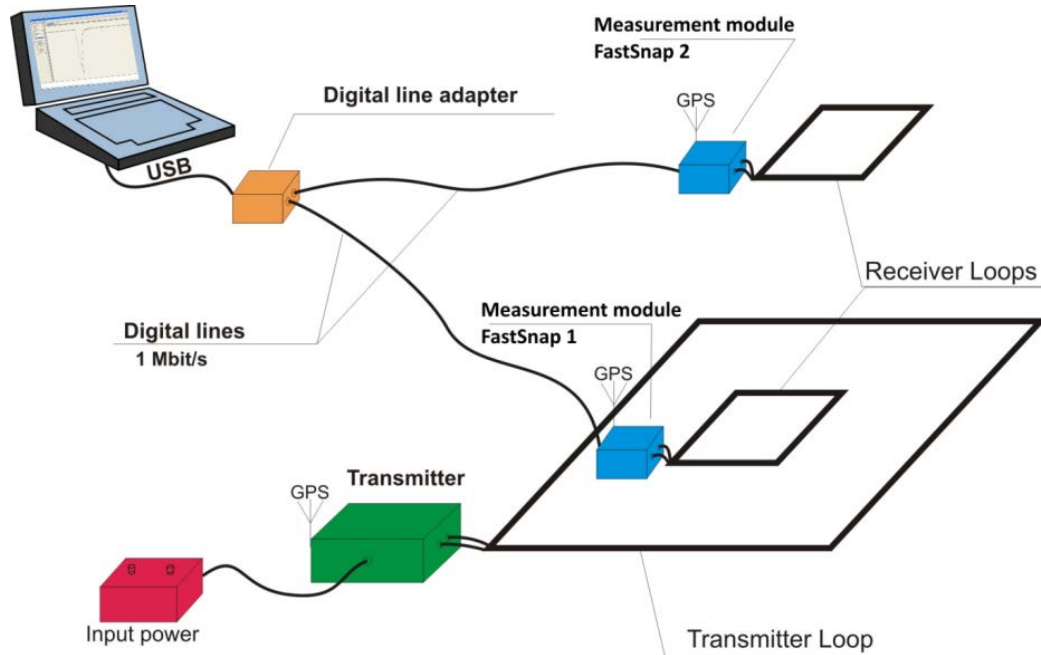


Figure 19. Connection scheme of two-channel configuration of *FastSnap* equipment

Before using of equipment in field conditions please be sure that all units and cables are in good condition and devices have all batteries installed and charged of properly.

Order of preparation and connection of elements of equipment is as follows:

1. Select the most convenient place for the field notebook for the further acquisition (workplace of field operator) and connect digital line adapter (DLA) to laptop;
2. Deploy transmitter loop on the desired place of exploration line or area (for additional information see [Section 3](#) of this User Guide);
3. Setup receiver loop(s) on the defined positions of recording (for additional information see [Section 3](#) of this User Guide);
4. Install transmitter unit near the transmitter loop's corner;
5. Install receiver unit(s) near the receiver loop(s);
6. Connect receiver loop(s) to respective receiver unit(s) through the proper input cable (Fast or STD ADC cables – depends on depth of investigation and sizes of loops, for further information see [Section 3](#) of this User Guide);
7. Unroll and connect digital wire line(s) (through the RX LINE cable, see [Section 2.1.2](#)) from receiver unit(s) to DLA through the DLA cable (streamer);
8. Connect transmitter loop to the transmitter unit (refer to [Section 2.1.4.3](#));
9. Select how the transmitter unit will be managed (through the DLA TX CONTROL port (RS232) or in the manual mode via the CONTROL PANEL (refer to [Section 2.1.4.4](#))) and connect or *control and synchronization* cable to DLA;

10. Setup power batteries near the transmitter unit (connect them serially if higher DC voltage is required) and connect to transmitter unit through the special TX POWER cable (see Section [2.1.4.2](#));
11. Run *FastEM* software on the laptop and check that all units are connected and operating correctly (refer to the *FastEM registration* software User Guide);
12. Perform acquisition and save obtained data to database (refer to the *FastEM registration* software User Guide);
13. Uninstall survey system, collect all units/cables/wires and move to next position of data acquisition.

Note! Use external 12 V batteries for receiver and/or transmitter unit when internal batteries are become discharged (see Sections [2.1.2.1](#) and [2.1.4.1](#)).

3. Using *FastSnap* for TEM surveys

3.1. Applicability of the TEM method

The *FastSnap* instruments are designed for electromagnetic resistivity surveys, including the transient electromagnetic (TEM) method.

EM surveys apply to various problems in geosciences aiming at differentiation of rocks according to their electrical properties. The resistivity of rocks varies in a large range. Rocks of the same lithology, especially sediments, may have different resistivities depending on their physical state, burial depth, structure, temperature, etc. The key controls are:

- mineralogy;
- fluid type;
- structure and texture (mineral matrix and cement);
- porosity;
- water content;
- pore water salinity;
- temperature.

Main applications and targets of the *FastSnap* system:

1. Mapping aquifers (hydrogeology):

- freshwater;
- saline groundwater;
- thermal water.

2. Engineering, environmental mapping, archaeology:

- soft sediments (including implications for geological hazard, recurrent or not);
- karst;

- environmental objects (including pollution with hydrocarbons or brines);
- monitoring surface processes (water regime, landsliding, etc).

3. Mineral exploration:

- base and rare metals;
- lode and stratified ore deposits.

4. Near-surface surveys:

- subaerial sediments and their electrical properties;
- permafrost;
- graphite- or pyrite-bearing and other n -conducting rocks;
- structural patterns and tectonics (fault displacements);
- igneous rocks;
- petroleum exploration.

3.2. TEM method: Theory

Transient electromagnetics (also time-domain electromagnetics/TDEM), is a geophysical exploration technique widely used in Russia for numerous geoscience applications from near-surface environmental studies to petroleum exploration. An important contribution into the theory and development of the method belongs to A.N. Tikhonov, L.L. Vanyan, S.A. Sheinmann, B.I. Rabinovich (in Russia), G.V. Keller, J.R. Wait, L. Buselli, C.H. Stoyer, J.M. Reynolds (in other countries), and many others.

TEM is a controlled-source induction resistivity survey method. The sources and receivers of the electromagnetic (EM) field are most often high-tech loop-loop or central-loop (in-loop) configurations which require no ground and can run in any season.

The primary EM field is generated by switching the transmitter current off in a controlled fashion (Fig. 3.1). Once the primary field is switched off, the EM wave induces eddy currents within buried conductors that in turn produce a secondary field decaying with time and migrating downward in a spiral of increasing width.

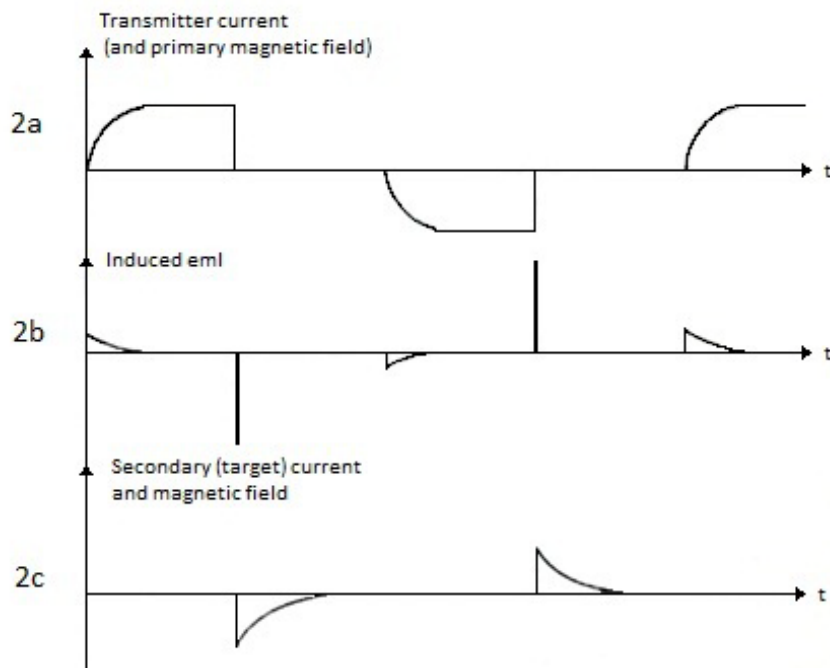


Fig. 3.1. Transmitter current waveforms and voltage decay curves: A is primary magnetic field, B is induced electromotive force (emf) or voltage, C is secondary magnetic field.

Voltage induced in the receiver coil depends in an intricate way on the transmitter current, system configuration, and the electrical properties of the sounded earth.

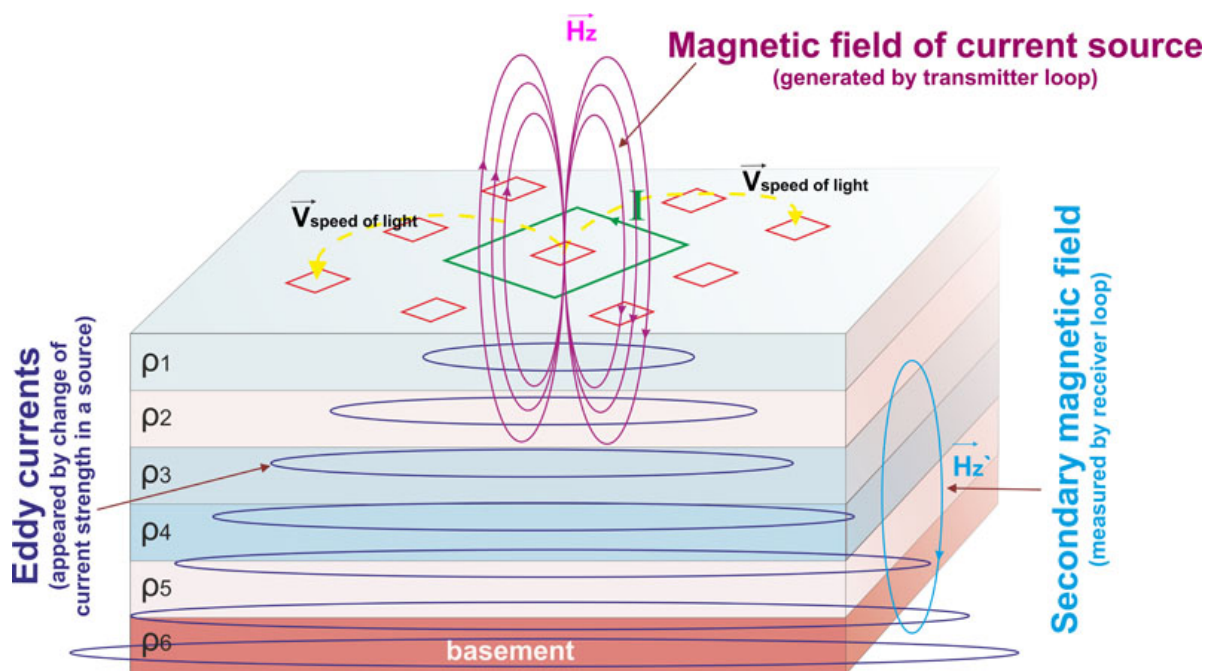


Fig. 3.2. Induction of eddy currents.

The EM field of an electric or magnetic dipole consists of two parts: one propagating into non-conducting air at a light speed almost without losses and incident vertically on the earth, and the other traveling through conducting earth and subject to attenuation. The signal penetrates to the far-field zone at $R/H > 4$ and to the near-field zone at $R/H < 1$, where R is the transmitter-receiver distance and H is the depth to the target. The right part of the field penetrates farther

than a wavelength while the left field part attenuates almost to zero. Waves in the air propagate along the earth surface almost instantaneously and penetrate simultaneously downward at all far-field points, i.e., show plane-incidence behavior, while waves in the earth travel at a finite speed and decay more or less strongly as a function of the earth's electrical properties. The near-field vertical magnetic component depends only on conductivity and is independent of the distance to the source.

The sources and receivers in TEM field surveys are commonly multi-offset systems with square loops.

$$\Delta U_q = -\mu_0 S \frac{\partial H_z}{\partial t},$$

where μ_0 is the vacuum magnetic permeability.

Processing TEM data consists in deriving apparent resistivities ρ_τ from decaying voltage values at different transient times. In the case of the loop-loop configuration, ρ_τ is given by

$$\rho_\tau(t) = \frac{\mu_0}{\pi t} \cdot \left(\frac{Qq\mu_0 I}{20t\Delta U_q(t)} \right)^{\frac{2}{3}},$$

where Q and q are the effective areas of the transmitter and receiver loops, respectively (with different numbers of coils), t is the transient time (the decay time of the secondary field), $\Delta U_q(t)$ is the receiver voltage, I is the transmitter current, and $\mu_0 = 4\pi \cdot 10^{-7}$ H/m is the vacuum magnetic permeability.

In addition to the apparent resistivity $\rho_\tau(t)$, the voltage decay curves can be transformed to depth-dependent total conductivity (Sidorov-Tikshaev transformation), where the apparent conductivity $S_\tau(h_\tau)$ reflects the integral conductivity to the depth h_τ :

$$S_\tau(h_\tau) \approx \int_0^{h_\tau} \frac{1}{p(z)} dz,$$

the function $p(z)$ being the depth dependence of resistivity.

TEM data are commonly interpreted with a layered-earth assumption. Inversion is performed by fitting theoretical electric parameters of rocks to observed apparent resistivity and conductivity patterns.

3.3. Fundamentals of field TEM surveys

3.3.1. TEM systems

The *FastSnap* TEM system uses ungrounded square transmitter and receiver loops of different sizes. The transmitter coil is made of a durable single-turn copper wire and the receiver coil may be single-turn or multi-turn copper wire. The receiver can be laid either outside (Q-q) or inside (Qq) the transmitter loop.

A combined configuration is commonly recommended, with two receivers laid outside and inside a single transmitter loop at a distance equal to its size (Fig. 3.3).

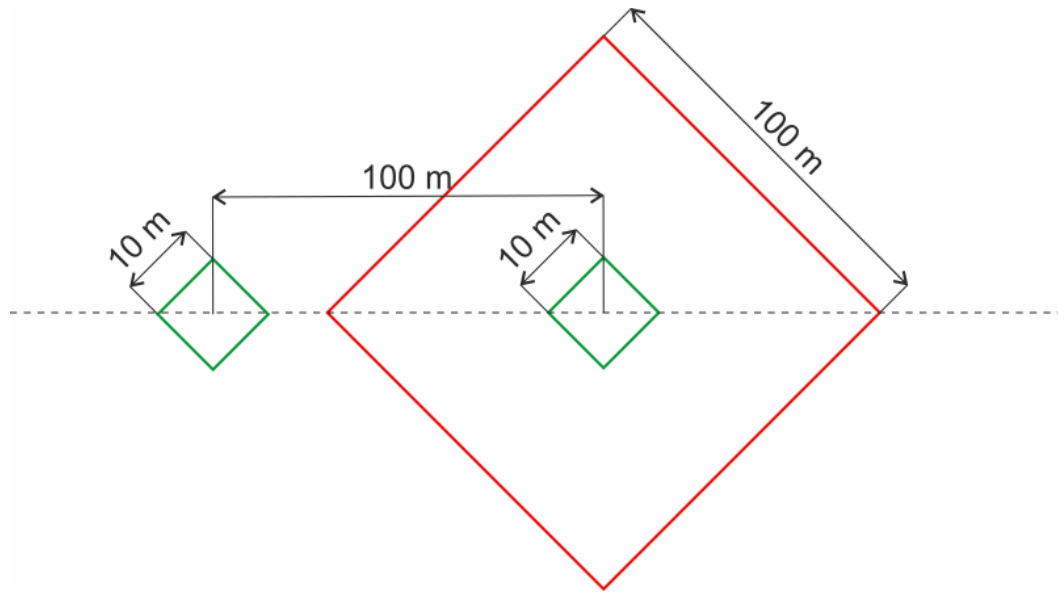


Fig. 3.3 Combined off-loop/in-loop configuration. Red and green lines are transmitter and receiver cables, respectively.

There are “diagonal” or “pipelined” modes of loop laying (Figs. 3.4 and 3.5, respectively). In the former case, the cable is laid left- and right-ward from the opposite diagonal corners till the respective reciprocal segments meet to make a square (Fig. 3.4). This way works well in hardly accessible terrains, while the other way (Fig. 3.5) is better suitable to open lands.

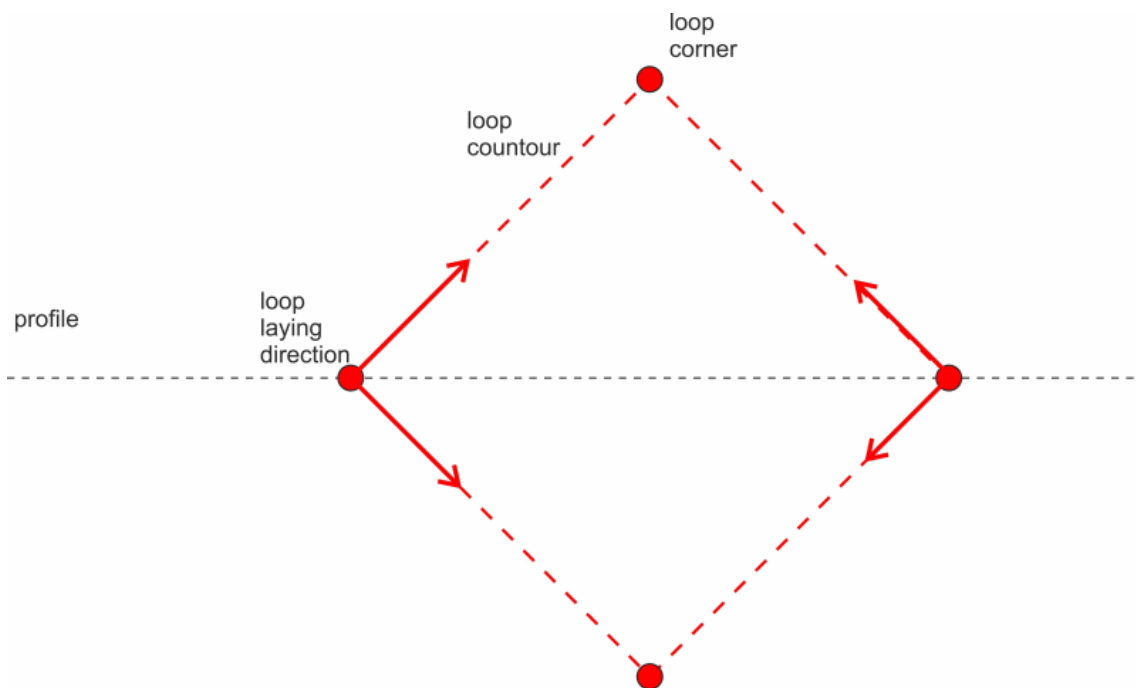


Fig. 3.4 Diagonal loop laying.

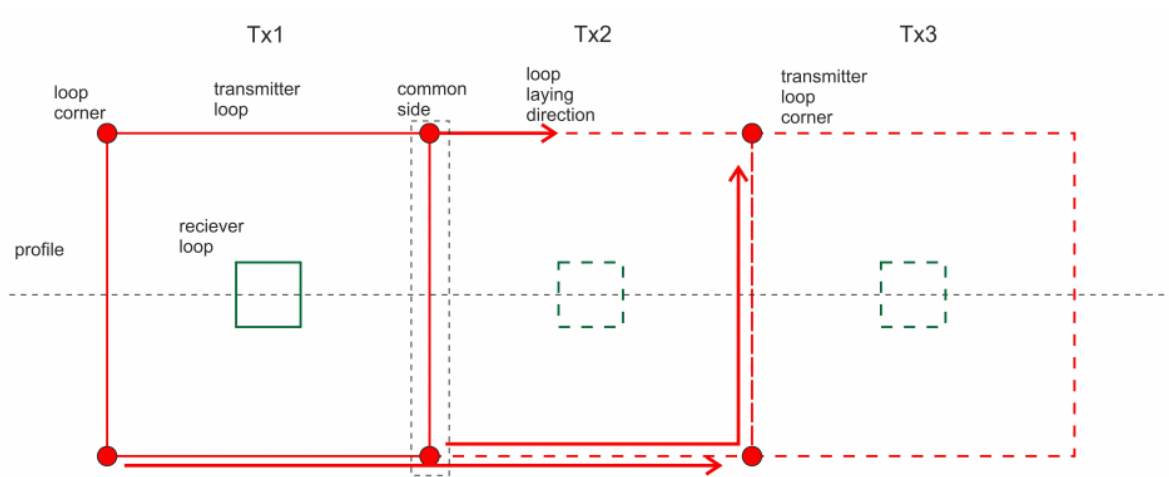


Fig. 3.5 Pipelined loop laying.

Mapping and survey design are performed using the *GeoMap* information system, and the sounding points are placed using *Garmin GPS* stations; the loop directions are adjusted with a surveying compass.

The advantages of the TEM method are: site-specific sounding, large exploration depth, weak sensitivity to anisotropy and near-surface heterogeneity, ungrounded loops that can work in any terrain and in any season, and depth resolution higher than in other resistivity survey methods (dc or natural EM fields).

3.3.2. Choice of sounding configuration

The transmitter and receiver loop sizes are chosen such that they provide

- optimum starting and final sounding depth;
- high signal-to-noise ratio (SNR) over the whole range of transient times;
- least possible effects of induced polarization and magnetic viscosity (frequency dependence of conductivity).

The design sounding depth is the key factor in the choice of the transmitter loop dimensions. The loop size required to reach a certain depth of exploration is estimated as

$$H \approx a \times L,$$

where H is the depth, L is the transmitter loop size (side length), and a is a coefficient that can take the values 3, 4 or 5 depending on the noise level and local resistivity distribution.

The effective sounding depth in the TEM method is known to depend on the length of the transient response (transient time). However, the true depth is limited by SNR as the induced voltage decays rapidly after the transmitter current turn-off. The higher the SNR the larger the times (depths) that can furnish useful information. SNR depends on the transmitter and receiver magnetic moments, as well as on the noise level.

The magnetic moment of the transmitter (M_Q) is

$$M_Q = Q \times I \times n ,$$

where Q is the loop effective area, I is the current, and n is the number of turns in a coil.

The larger the transmitter loop size the deeper the sounding. However, the starting depth should be large enough as well, because the travel-time of the EM wave depends on the transmitter loop size (as the TEM system is non-dipole). Namely, the larger the transmitter the longer the time in which the EM field can reach the in-loop receiver inside it ($t_1 > t_2$), i.e., the far-field zone shows up at early times (Fig. 3.6).

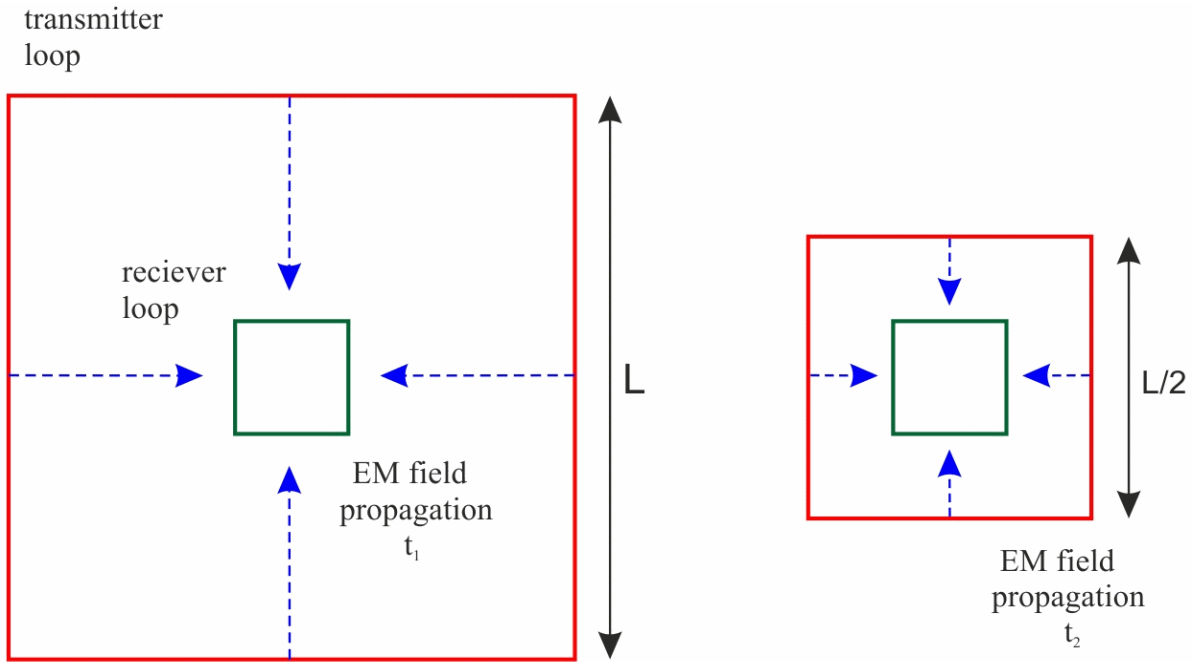


Fig. 3.6 The transmitter size dependence of EM wave travel time.

In apparent resistivity curves $\rho_t(t)$, this effect shows up as a descending branch at early times (Fig. 3.7). The larger the transmitter size, the more the asymptotic left-hand curve branch shifts to the right. Correspondingly, the records miss the early-time near-surface information.

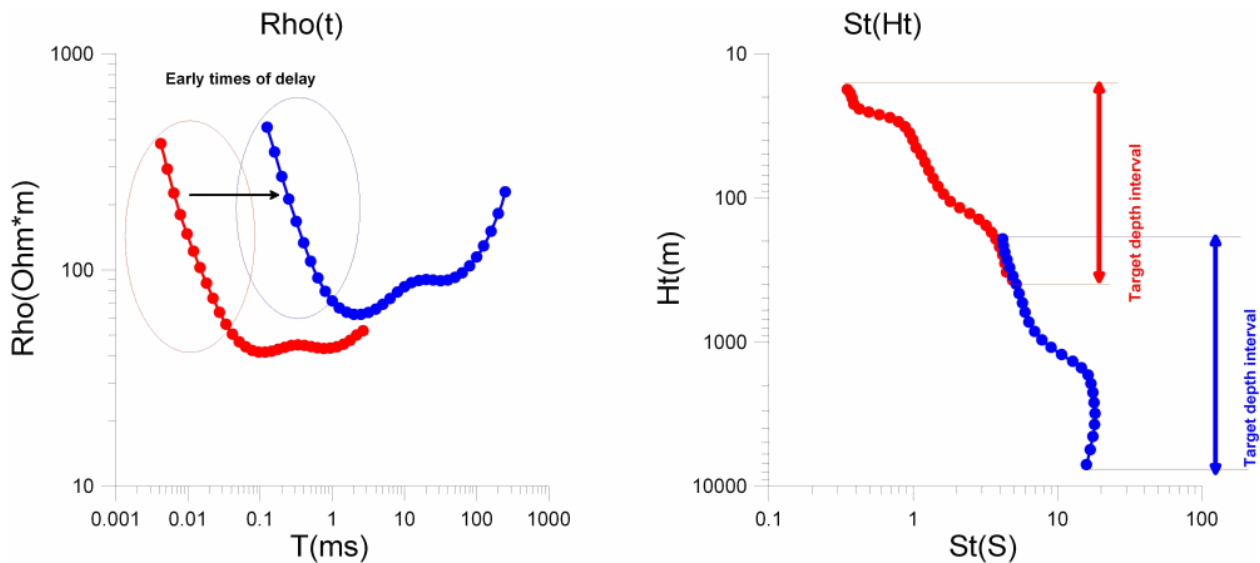


Fig. 3.7 TEM responses recorded by systems with large and small transmitter loop sizes (blue and red colors correspond, respectively, to 500×500 m and 100×100 m loops).

Before addressing the receiver loop parameters, it is pertinent to discuss the receiver path of *FastSnap*. The *FastSnap* receivers have a dual-bit (14 and 24) ADC: the 14 bit ADC provides high-resolution early time recording (sampling at every 25 ns) in the case of a short transient process while the 24 bit ADC allows recording in a broad range of amplitudes (at lower resolution and a larger stepsize up to 200 μ s) and at later times. Thus, the depths of sounding with a *FastSnap* system may range from few meters to many hundreds of meters. The transient responses of shallow earth are recorded using the 14 bit ADC (fast input), at a dynamic range of ± 1 V. Large loop sizes in this case may cause overshooting at both early and late times if the noise is strong; the receiver loop size should be chosen proceeding from the ratio

$$l \approx \frac{L}{b},$$

where l is the receiver loop size, L is the transmitter loop size, b is the coefficient (from 5 to 10 as a function of noise and local resistivity pattern).

The 24 bit ADC is more efficient for medium and large depths (standard input); in this case, the receiver coil may be large or multi-turn.

The magnetic moment of the receiver (M_Q) is

$$M_Q = q \times n,$$

where q is the loop effective area and n is the number of turns.

The optimum magnetic moment of the receiver loop is

$$q \approx (0.25 \div 0.5) L^2,$$

where q is the receiver loop effective area and L is the transmitter loop size.

The receiver may have twice or four times smaller effective area than the transmitter loop.

The recommended loop sizes and respective sounding depths are listed in the table below.

Table 6. Recommended loop sizes and respective depths of exploration.

Loop size, m		Sounding depth, m		Recommended input	ADC
Q (transmitter)	q (receiver)	Starting	Final		
25×25	5×5	5	100	Fast	
50×50	5×5, 10×10	10	200	Fast	
100×100	10×10, 20×20	20	400	Fast	
200×200	10×10, 20×20	30	600	Fast	
300×300	multi-coil loop	50	700 - 900	Standard	
500×500	multi-coil loop	100	900 - 1500	Standard	

Unwanted IP and magnetic viscosity effects in TEM data can be attenuated by changing the system geometry. The density of IP and MV field lines is the highest inside the transmitter loop and decreases away from it. Thus, there are two possibilities:

1. setting the receiver loop off the transmitter at a distance where the IP and MV effects are the weakest (chosen empirically);
2. increasing the loop size, whereby the density of IP and MV field lines decreases, and the effects become weaker correspondingly.

3.3.3. Off-loop configuration

Many years of experience running TEM surveys in different physical and geological settings has shown the combined off-loop (Q-q) and in-loop (Qq) configuration to be the most efficient. It allows sounding simultaneously at several points, and thus at a higher performance than with the conventional configuration. Furthermore, the acquired data provide evidence of the earth homogeneity important for quantitative interpretation. The in-loop and off-loop responses of a layered earth converge at late times (Figs. 3.8, 3.9).

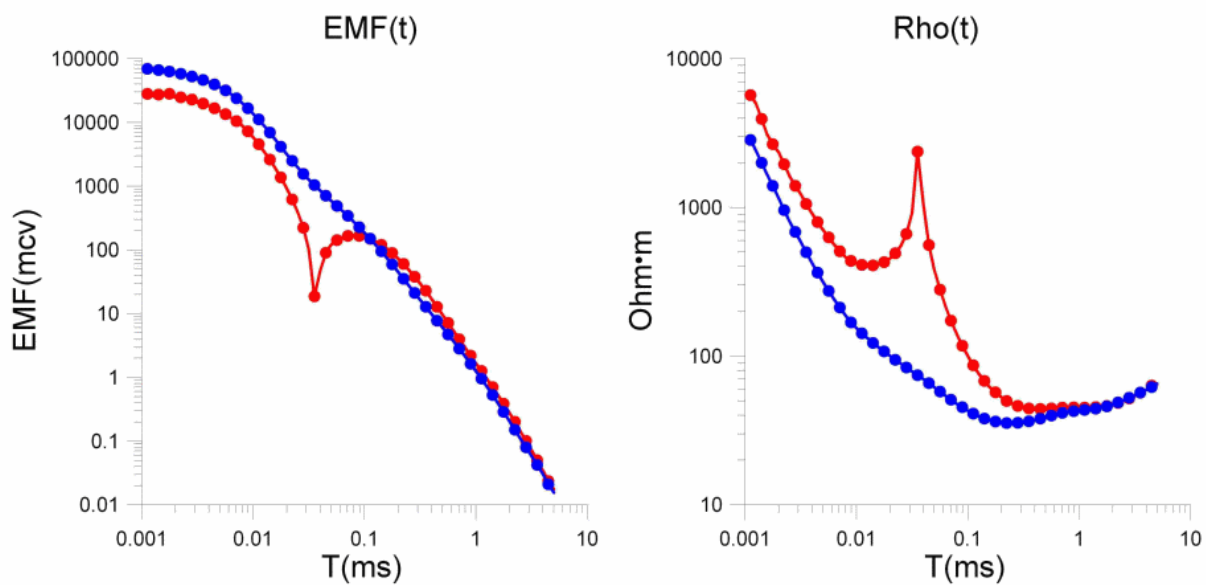


Fig. 3.8 Typical $\text{emf}(t)$ and $\rho_t(t)$ responses of a layered earth (blue and red colors correspond to loop spacing of 0 and 100 m, respectively).

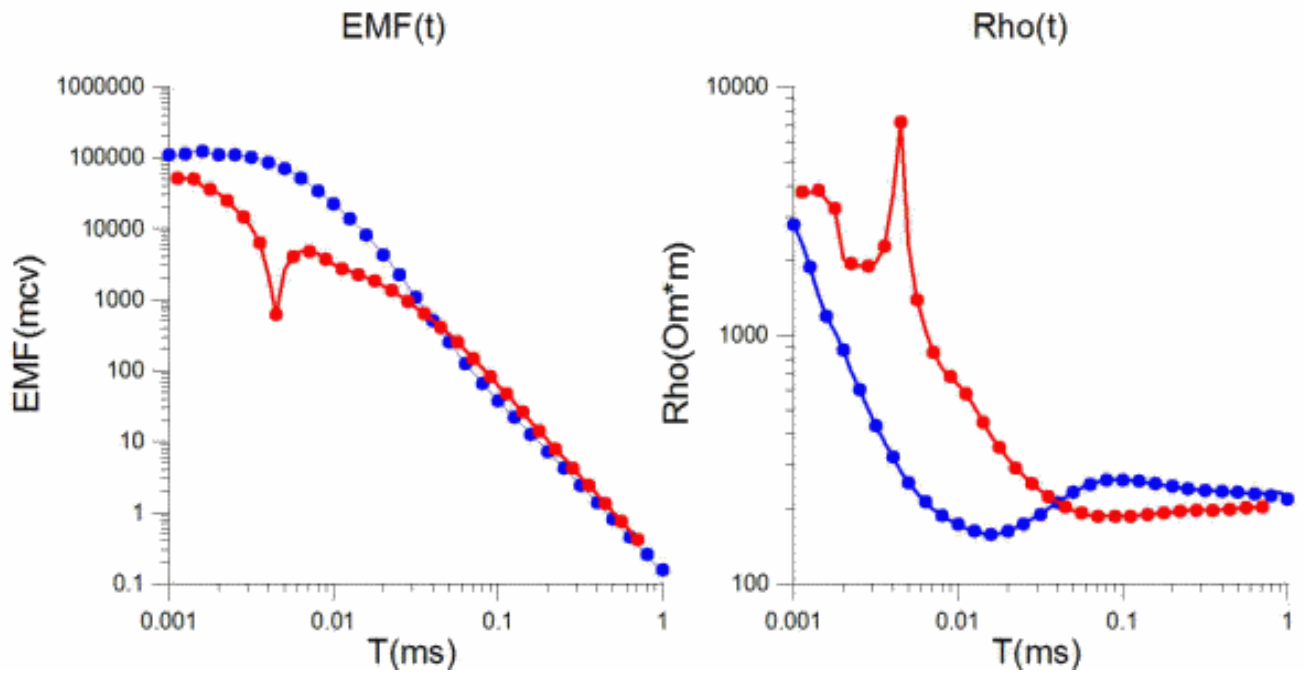


Fig. 3.9 Typical $\text{emf}(t)$ and $\rho_t(t)$ responses of a heterogeneous earth (blue and red colors correspond to loop spacing of 0 and 100 m, respectively).

The earth homogeneity can be also checked by means of two-fold coverage, with a single receiver recording signals from two transmitters set at the same distance (Fig. 3.10). A homogeneous layered earth will respond in the same way in both records.

Quantifying 3D heterogeneity effects obviously requires 3D modeling of transient responses. In this case, multi-offset surveys can be useful which allow estimating earth heterogeneity, as well as effects of frequency dependent conductivity: induced polarization (IP) and magnetic viscosity (MV) or paramagnetism.

The estimation of IP effects with the multi-offset configuration stems from the fact that the IP field is much lower outside the transmitter than in its center. The in-loop responses of a polarizing earth decay more rapidly than the off-loop responses. See Figures 3.11 and 3.12 for the fast-decaying IP effects at early and late time, respectively

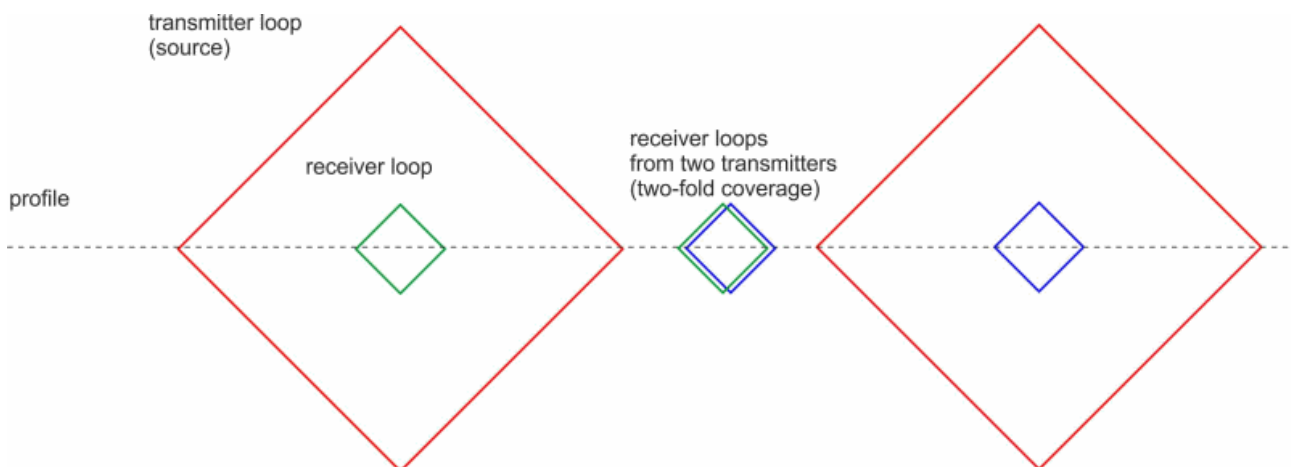
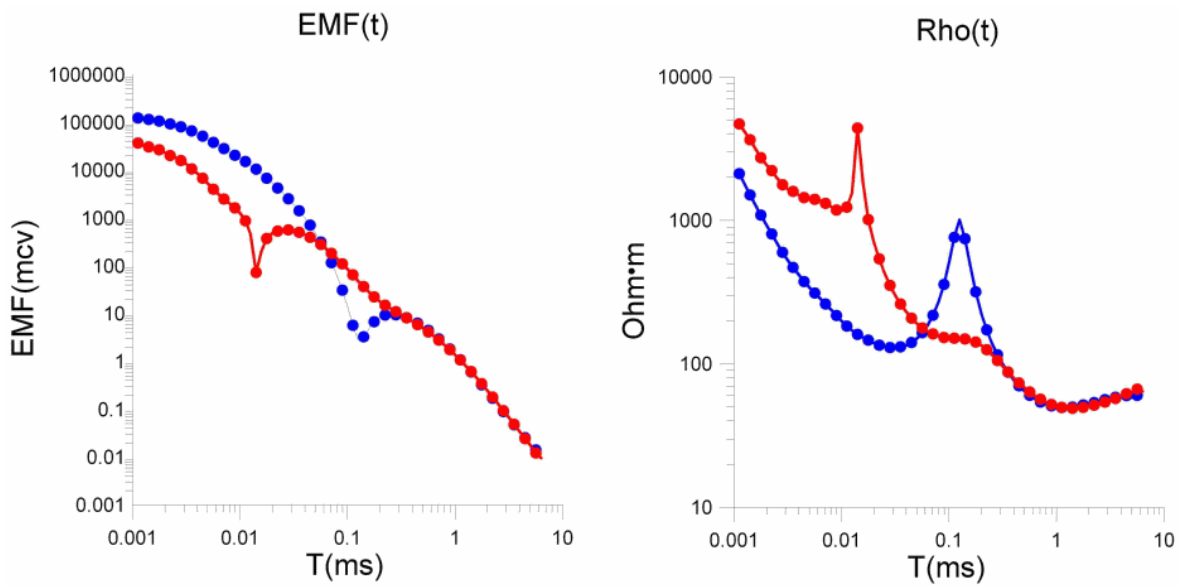
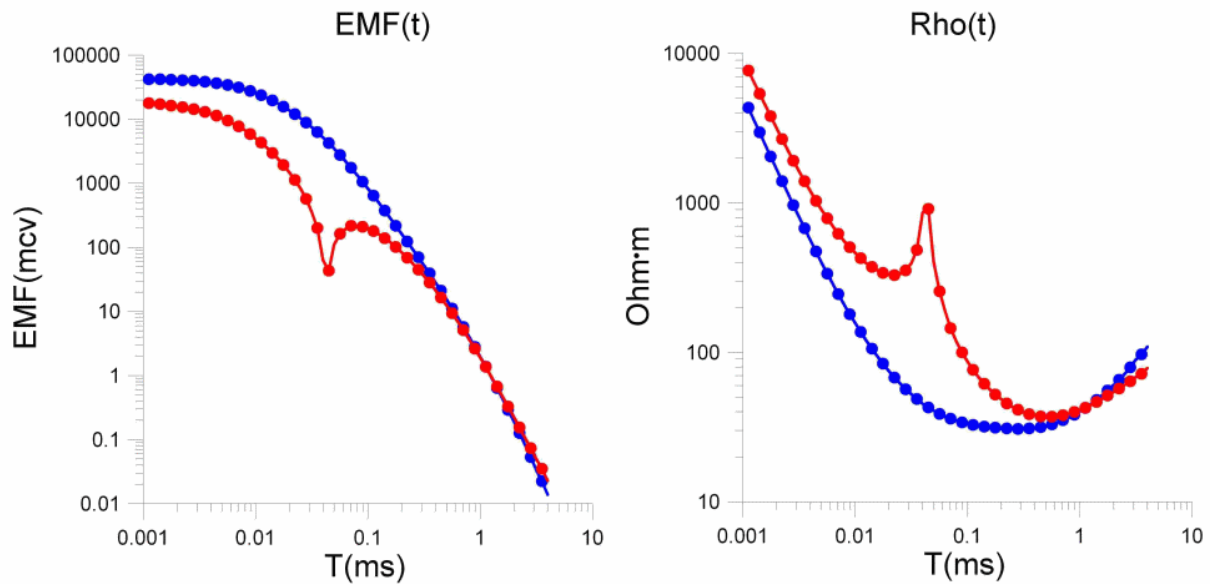


Fig. 3.10 Two-fold coverage.



3.11 Typical $\text{emf}(t)$ and $\rho_t(t)$ responses with fast-decaying IP effects at early times (blue and red colors correspond to loop spacing of 0 and 100 m, respectively).

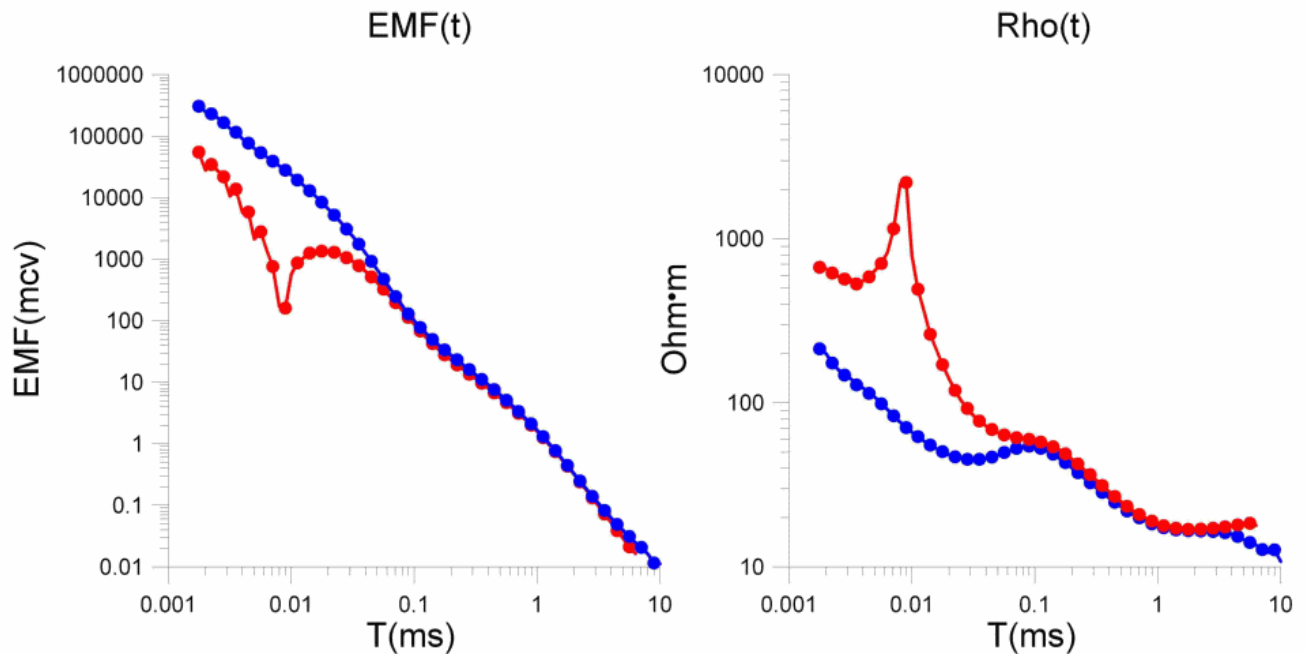


3.12 Typical $\text{emf}(t)$ and $\rho_t(t)$ responses with fast-decaying IP effects at late times (blue and red colors correspond to loop spacing of 0 and 100 m, respectively).

Interpretation of TEM curves without due regard to IP and MV effects will be obviously incorrect. Currently the patterns of fast-decaying induced polarization have been studied well enough to be accounted for in forward modeling. Therefore, multi-offset TEM data can be inverted to the electric parameters of rocks bearing signature of fast-decaying IP. The IP effects being less pronounced in off-loop TEM responses, the in-loop responses are inverted with reference to largest-offset data. The next step consists in fitting the parameters of fast-decaying IP to observations (minimizing the misfit between measured and computed TEM curves).

The magnetic viscosity effect shows up in a complex way. The in-loop responses decay more slowly at late times (Fig. 3.13). The responses acquired at large offsets are less strongly affected by magnetic viscosity (the density of MV field lines decreases away from the transmitter).

Paramagnetism is quite a rare effect but it's neglect in the inversion of in-loop responses may lead to false conductors in the lower part of resistivity models. In this case, the model is checked against off-loop data.



3.13 Typical $\text{emf}(t)$ and $\rho_t(t)$ responses with magnetic viscosity effects (blue and red colors correspond to loop spacing of 0 and 100 m, respectively).

Thus, the use of multi-offset and multi-fold coverage acquisition is a simple and efficient way for checking the layered-earth approximation and the frequency dependence of conductivity (IP and MV effects).

3.4. Phases of work

3.4.1 Reconnaissance

Reconnaissance of the terrain before test and production surveys aims at detection and assessment of factors that may influence the acquisition process and the quality of the acquired data. Namely, roadways, vegetation, transmission and pipe lines, urban territories, and other potential sources of cultural noise and complications. The reconnaissance survey consists in mapping the indicators of the road state and the terrain accessibility and in recording GPS tracks for the purpose of survey design with the *Project Manager* software.

3.4.2 Survey design

All data collected during reconnaissance are brought together into the *Project Manager* program for survey design, which is a key phase in the field work with the *FastSnap* system. The observation network is designed with reference to this information according to the geological objective. The design database includes the numbers assigned to each transmitter and receiver placed at a pre-specified spacing along the profile. For more details on the survey design phase see the guide to the *Project Manager* software.

3.4.3 Test surveys

Testing is always performed before any production surveys in order to provide the best data quality. The main goal of testing is to make the best choice of survey conditions and methods, namely

- acquisition parameters;
- system configuration (to reach the wanted sounding depth);
- technologically most advanced and efficient methods.

Testing consists in preliminary surveys with the chosen method, including specifying preliminary acquisition parameters, recording transient responses, on-site data processing, analysis of the processed data and assessment of their quality.

3.4.4 TEM data acquisition

The production surveys with the acquisition parameters and geometry chosen during the phases 3.4.1 through 3.4.3 are run with the recording systems deployed successively over the survey area in real conditions. The raw acquired data are recorded voltage decay curves saved as such in the database.

Most of the information saved to the digital database is additionally stored in logs the operators keep manually while recording, along with other data used for office processing. The raw data are further processed and checked on the site. For more raw data processing details see the guide to the *TEM-Processing* software.

3.4.5 Data interpretation

Interpretation of TEM data is a complex process. Office processing implies inversion of the measured transient responses to earth resistivity patterns and comprises two main steps (Fig. 3.14).

Qualitative interpretation: viewing voltage decay curves $emf(t)$ or their apparent resistivity $R_t(t)$ and conductivity $St(Ht)$ transformations in the profile form (their vertical and lateral variations and correlations), in order to choose a preliminary model to be further updated during inversion.

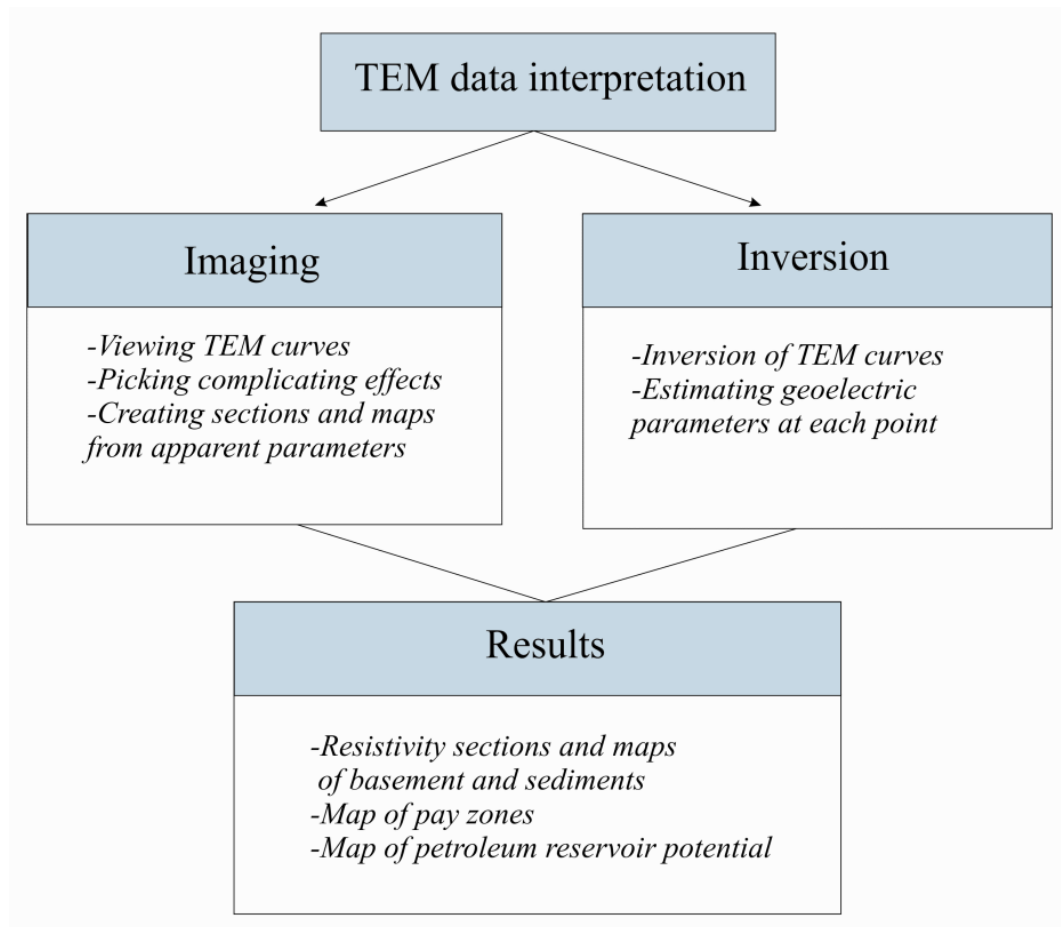


Fig. 3.14 Workflow of TEM data interpretation.

Quantitative interpretation: simulation of a layered earth with its parameters specified according to wire-line logging and other geophysical methods.

The starting models are created proceeding from the total conductivity of layers, with their tops and bases constrained by *a priori* information. The layer thicknesses are locked in order to reduce equivalence, which improves the inversion quality (to few percent error), given that the layer thicknesses are within $\frac{1}{4}$ of the sounding depth. There are two main criteria of inversion quality for the spatial data:

- fit of computed curves to the measured responses (minimum error);
- similarity of models derived from nearby responses.

Inversion of transient responses is run by fitting the computed curves to the observations (error minimization). The inverse solution is theoretically unique for a layered earth, but may become ambiguous and unstable because of instrument and computation errors. The ambiguity

results from equivalence (existence of several resistivity models that fit the same TEM curve). The equivalence can be reduced by checking against independent geological and geophysical evidence. More difficulty may arise with laterally heterogeneous sections that bear 3D features. For more details of the interpretation issues see the guide to the *Profile* and *Model* software packages.