Monitoring of apparent resistivity variations, electromagnetic emission and ionosphere effects in the audio- and radio frequency ranges
Overview

1. General approach
2. Instruments
3. Apparent resistivity variations measurements
4. Electromagnetic emission registration
5. Ionosphere disturbances study
General approach

✓ application of digital instruments with registration of time series of investigated parameters in wide frequency range:
   0.1 Hz – 1 MHz or ULF – ELF – VLF – LF – MF

✓ minimum number of instruments types with the possibility of simultaneous multi-parametric registration;

✓ possibility of measurements in conditions of the raised noise level;

✓ development and application of the technique of tensosensitive zones selection for the equipment installation;

✓ rather small expenses for equipment installation and operation.
Electromagnetic earthquake precursors investigated

✓ Apparent resistivity variations (frequency range 0.1–1000 Hz)

✓ Electro telluric anomalies (frequency range 0.1-1 Hz)

✓ Electromagnetic emission anomalies from time series measurements (frequency range 0.1 Hz – 1 MHz)

✓ Ionosphere disturbances registration using measurements:
  • signals from remote radio transmitters in radio frequency range (10 kHz – 1 MHz)
  • natural electromagnetic field Schumann resonances in the audio frequency range (8-45 Hz).
Electromagnetic monitoring instruments
# The audiomagnetotelluric ACF-4M system

## Recorder

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of channels</td>
<td>4</td>
</tr>
<tr>
<td>ADC, bits</td>
<td>24</td>
</tr>
<tr>
<td>Frequency range, Hz</td>
<td>0.1-1600</td>
</tr>
<tr>
<td>Frequency resolution, Hz</td>
<td>0.0005-12.5</td>
</tr>
<tr>
<td>Internal memory, Mb</td>
<td>512</td>
</tr>
<tr>
<td>Adapter for connection to PC</td>
<td>Ethernet</td>
</tr>
<tr>
<td>Display</td>
<td>LCD, monochrome, 320x240</td>
</tr>
<tr>
<td>Keypad, keys</td>
<td>18</td>
</tr>
<tr>
<td>Built-in accumulator, 5 A*h, V</td>
<td>12</td>
</tr>
<tr>
<td>Built-in accumulator, operation, hours</td>
<td>14</td>
</tr>
<tr>
<td>External battery, V</td>
<td>12</td>
</tr>
<tr>
<td>Operating temperature, ° C</td>
<td>-20 to +50</td>
</tr>
<tr>
<td>Dimensions and weight</td>
<td>mm kg</td>
</tr>
<tr>
<td>340x295x155  4.0</td>
<td></td>
</tr>
</tbody>
</table>

## Magnetic coil

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range</td>
<td>0.1-4000 Hz</td>
</tr>
<tr>
<td>Transfer constant</td>
<td></td>
</tr>
<tr>
<td>- frequency range 0.5-1000 Hz</td>
<td>80 mV/nT</td>
</tr>
<tr>
<td>- frequency range 0.1-0.5 Hz</td>
<td>160 mV/(nT*Hz)</td>
</tr>
<tr>
<td>Noise level</td>
<td></td>
</tr>
<tr>
<td>- frequency 10 Hz</td>
<td>12 fT/√Hz</td>
</tr>
<tr>
<td>- frequency 1000 Hz</td>
<td>2.5 fT/√Hz</td>
</tr>
<tr>
<td>Voltage of external power supply</td>
<td>±(7-10) V</td>
</tr>
<tr>
<td>Current consumption</td>
<td>18 mA</td>
</tr>
<tr>
<td>Dimensions and weight</td>
<td></td>
</tr>
<tr>
<td>70 x 1110 mm</td>
<td>5 kg</td>
</tr>
</tbody>
</table>

## Magnetic sensor
## The RMT-F radiomagnetotelluric system

### Recorder
- **Number of channels**: 4
- **ADC, bit**: 16
- **Frequency range, kHz**: 1-1000
- **Internal memory, Mb**: 2048
- **Adapter for connection with PC**: Ethernet
- **Display**: LCD, monochrome, 320x240
- **Keypad, keys**: 18
- **Built-in accumulator, 5 A*h, V**: 12
  - **operation, hours**: 8
- **External battery, V**: 12
- **Operating temperature, ° C**: -5 to +50
- **Dimensions and weight of measuring unit**: 340x295x155, 4.0 kg

### Magnetic sensor
- **Frequency range, kHz**: 10-1000
- **Transfer constant, mV/(nT*Hz)**: 25
- **Dimensions and weight**: 40 mm (diameter), 240 mm (length), 0.2 Kg (weight)
- **Noise level, pT/√Hz**: 0.4
- **Voltage of external power supply, V**: ±8
- **Current consumption, mA**: 30
- **Cable length, m**: 2
Features of measurements with the ACF-4M system

- Time series
- Dynamic spectrum
- Autospectra and coherence
- Curves of apparent resistivity and impedance phase
Features of measurements with the RMT-F system

Time series

Autospectra and coherence (100-1000 kHz)

Autospectra and coherence (10-100 kHz)

Curves of apparent resistivity and impedance phase
Apparent resistivity variations

Deep, middle-depth or shallow soundings for apparent resistivity variations measurements?
Apparent resistivity variations

- Frequency range

Pseudosection presentation of apparent resistivity and phase vs. date (May–August 2008) with earthquake incidents indicated.

Daily data is based on 24-hour segment, and earthquakes indicated are of M4.0 or greater.
Apparent resistivity variations

- Frequency range

Curves of apparent resistivity and impedance phase on 34 one-hours measurements, 18-19 March 2007, test site Ladoga, Leningrad region.

Curves of apparent resistivity and impedance phase on 50 one-hours and 23 two-hours measurements, 13-17 June 2008, test site Pasha. Red lines – curves in the period of strong magnetosphere radiation.
Apparent resistivity variations

- Tensosensitive zones selection:
  - Low thickness of overlying sedimentary rocks
  - High resistivity of basement’s rocks
  - High degree of medium heterogeneity, which indicates the faults presence
  - Registration of tidal variations of apparent resistivity at short testing monitoring

Sites for monitoring with low noise level are selected
Apparent resistivity variations

- Tenzosensetive zones selection

Monitoring at sites in Kyrgyzstan, Bishkek region

AMT sounding curves at the sites
Tash Bashat and Uch Emchek

Results of monitoring at the sites Tash Bashat (4.06.2005) and Uch Emchek (27.05.2005)
Apparent resistivity variations

- Tensosensitive zones selection

Monitoring at a site in St. Petersburg region, the Karelia isthmus

Results of monitoring at a site on the Karelia isthmus (26.07.1998)
Electromagnetic emission registration

An example of magnetosphere disturbance in dynamic spectrum of magnetic field (ACF-4M instrument)
Ionosphere disturbances study

Frequency, Hz

Realization

Autospectra V^2/Hz

Schumann resonances

Ionosphere disturbances study
Conclusions

The developing electromagnetic monitoring technology is based on the use:

- registration in the wide frequency range (0.1 Hz - 1 MHz) complex of parameters connected with the rocks electric properties variations, electromagnetic emission and ionosphere disturbances

- minimum number of instrument types with multi parametric measurements;

- big attention for the selection and testing of tensosensitive zones;

- integrated approach to the monitoring data interpretation.
Thank you for your attention!