

A new approach to shallow-depth electromagnetic sounding

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Abstract

This paper presents an extensive review of currently available shallow-depth portable geophysical instrumentation for electromagnetic induction sounding and profiling and the main technical characteristics of the devices. A new ground-based multicoil shallow-depth device with a special arrangement of receiver coils is considered. The latter are placed on the line where the vertical component of the magnetic field from the source coil is zero. The spacing between the source and the receivers is used as a sounding parameter, along with a frequency. This increases the efficiency of the study of the upper section and the contrast between the sounding curves, which simplifies their interpretation. In studies of local anomalous objects, the use of the proposed method and instrumentation significantly improves the quality of geophysical data. The increase in sounding efficiency provided by these devices is demonstrated on both synthetic and real field data.

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Introduction

Induction sounding and profiling are widely used in shallow geophysics all over the world. The speed and ease of operation of the instrumentation and the quality of the information obtained by these methods determine their applicability for a wide range of problems: from the search of local objects to the identification of structural features of the upper section. The well-known compact sounding devices include GEM-2, EMS, DUALEM, CDM-Explorer (Manshtein et al., 2000; Taylor, 2000; Won et al., 1996). The following electromagnetic profiling instruments are extensively used: EM-31, EM-38, EMP-400, and CMD (McNeill, 1980). The layout of the coils of these instruments is shown in Fig. 1, and their main parameters are listed in Table 1. The effective depth shown in the table is calculated for coplanar coils oriented in the horizontal plane of the coils, as is done, for example, in (Callegary, 2007; McNeill, 1980). The part of the medium above the effective depth provides 70 % of the useful signal. It has also been shown that for the case of coplanar coils oriented in a vertical plane (i.e., orthogonal to the ground),

the effective depth is halved. In the case of orthogonally oriented coils in the Dualem instrument (Fig. 1), the effective depth is three times smaller (Taylor, 2000).

The above devices for induction sounding of the subsurface have a number of disadvantages. If the primary field is not compensated, the information content of the useful signal is significantly reduced as it is measured against the background of the primary-field signal with a much larger amplitude. Systems with primary-field compensation are more efficient, but their configuration and calibration require complex electrical circuits and design solutions (Manshtein and Balkov, 2013; Manshtein et al., 2000). Furthermore, in the case of devices in which all coils are located in one plane, one near-surface object may be associated with several images in maps, graphs, and sections, which complicates their interpretation. For example, for the EMS instrument, objects located at a depth of less than 1 m, give rise to several extrema in the signal (Balkov, 2011; Balkov et al., 2013a).

Considerable experience in the development (Balkov et al., 2013b; Manshtein et al., 2000) and application (Epov et al., 2012, 2016) of portable equipment for shallow-depth electromagnetic sounding and profiling has been accumulated at the IPGG SB RAS. Current efforts are directed at developing a new approach to shallow-depth induction sounding in which the source and receiver coils are spaced not only horizontally

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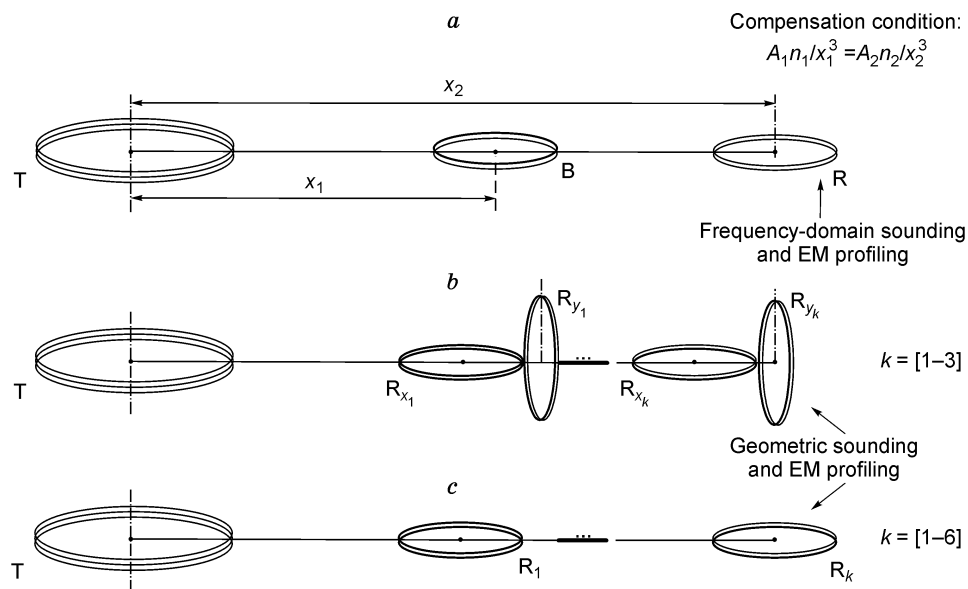


Fig. 1. Different configurations of compact equipment for shallow-depth induction sounding and profiling: *a*, EMS, GEM-2; *b*, Dualem-1, Dualem-21, Dualem-4; *c*, K-1 Em 31-MK2, Em38-MK2-1, EMP-400, CMD; K-2 EM38-MK2; K-3 CMD-EXPLORER; K-6 CMD-MINI-EXPLORER 6L. T is the source coil, B is the compensation coil, and R is the receiver coil.

Table 1. Shallow-depth induction sounding devices and their main characteristics

No.	Type	Device name	Frequency range, kHz	Spacing between the source coil and the receiver coil, m	Effective depth**
1	a	GEM-2	0.03–90	1.68	–
2	a	EMS	2.5–250	1.5*; 2.5	1–5
3	b	Dualem-1	9	1	1.5
4	b	Dualem-2	9	2	4
5	b	Dualem-21	9	1; 2	–
6	b	Dualem-4	9	4	6
7	b	Dualem-42	9	2; 4	6
8	c	EM31-MK2	9.8	3.66	6
9	c	EM31-SH	9.8	2	4
10	c	EM38-MK2-1	14.5	1	0.75
11	c	EM38-MK2	14.5	0.5; 1	0.3; 0.75
12	c	EMP-400	1.0–16	1.21	–
13	c	CMD-Explorer	–	1.48; 2.82; 4.49	2.3; 4.2; 6.7
14	c	CMD-Mini Explorer	–	0.32; 0.71; 1.18	0.5; 1; 1.8
15	c	CMD-Mini Explorer 6L	–	0.2; 0.33; 0.5; 0.72; 1.03; 1.5	0.3; 0.5; 0.8; 1.1; 1.6; 2.3
16	c	CMD Tiny	–	0.45	0.7
17	c	CMD 1	10	0.98	1.5
18	c	CMD 2	10	1.89	3
19	c	CMD 4	10	3.77	6
20	c	CMD 4/6	–	3.77; 5.79	9

Note. Dash indicates the absence of data from the manufacturer.

* Distance between the compensation coil and the source coil.

** Calculated for the horizontal coplanar arrangement of the coils (M_z – H_z mode).

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