Multifunction electroprospecting instruments for complex investigations, mapping, monitoring and exploration in a wide depth interval

Igor Ingerov
Advanced Geophysical Operations and Services Inc. (AGCOS), Toronto, Canada, info@agcos.ca

SUMMARY

The preference given to multifunction geophysical EM equipment in recent years is due to two things. On the one hand, the new technical features of modern instruments such as accuracy, wide frequency and dynamic band, similar software design for realization of different methods, intuitive operation, low weight, and portability. On the other hand, the economic considerations such as low cost, reduced net cargo shipping weight, smaller field crew size, required training time, etc. Another recent tendency is to add as many functions as it is economically feasible to multifunction equipment. The multifunction EM receiver GEPARD is largely in line with these tendencies. It has a wide frequency band (50,000-0.00005Hz), high sensitivity, wide signal band (0.1μV-10V), low power consumption, low weight, intuitive operation via touch screen user interface and several data transfer modes. GEPARD has a flexible configuration of channels (4 or 8), where any of the channels could be either electrical or magnetic and each channel has good EM noise protection and a combination of switchable, precise digital and analog filters. GEPARDs come equipped with induction coil magnetic sensors and low-noise non-polarizing electrodes, as well as a portable multifunction current source AT-100 with the corresponding frequency band.

Keywords: Electroprospecting, natural and control source electromagnetic field, magnetotellurics, resistivity, sensors.

INTRODUCTION

All existing EM instruments can be divided into 3 groups:

- specialized;
- semi-multifunction;
- multifunction.

Specialized instruments are usually designed to carry out field surveys by 1-3 EM methods with similar geometrical layout of the equipment in the field:

- EP, VES, IP, electrotomography (Saris, Syscal, Mery-24, Era-max, GRx8-32, etc.);
- TEM, IP (Tem-Fast, Sirotem, Protem, Impulse, Cycle-7, etc.).

Semi-multifunction instruments are meant for surveys by two or more methods with different nature:

- MT, IP (Titan-24, etc.).

Multifunction instruments are designed for carrying out surveys with several geophysical techniques where one of them is necessarily based on natural EM field variation measurements (MT, AMT, RMT and MVP). Any MT/AMT instrument is potentially multifunctional, but that instrument needs to have easy manipulation and control functions, such as keyboard, display, I/O, etc.

As we look further into multifunction EM instruments, we'd like to give brief history of its development based on the classification that was done by Fox (2005), Fox (2008), Ingerov (2005) and Ingerov (2011). They separated five generations of multifunction equipment capable of doing MT/AMT.

The first generation was designed in the former USSR in the 1950s-1960s (MTL-62, MTL-72 and others) and had 2 or 5 channels, analog amplifiers and filters. An oscilloscope and photo paper was used for EM signal recording. The instruments were lightweight, portable, had low power consumption, and quartz variometers were used as magnetic sensors. Instruments were widely used for MT, telluric current (TC), LowTEM, VES, DES surveys in the USSR countries in the 1950s-1970s. The main problem with the application of these instruments was manual data processing.

The second generation was designed at the end of 1960s/beginning of 1970s and was digital (CES-1 and CES-2, former USSR). EM field records were stored on magnetic tape and processing at centralized computer centers still took quite a bit of time. Equipment was heavy (about 200kg without accessories), had large power consumption (>200W) and had to be mounted on a truck. The second generation also used quartz variometers for measurements of magnetic components of the EM field. Hundreds of CES-1s and CES-2s carried out successful surveys during 1970s-1990s by MT, FDEMS, LowTEM and MulTEM.

The third generation of multifunction instruments was developed in early 1980s (for example, MT-16). The main features added were the on-board PC, which could provide real-time data processing, including a remote reference MT technique, and induction coils as the sensors for the magnetic components of the EM field. Equipment was still heavy and had large power consumption.

The fourth generation was designed in late 1980s and became portable with a built-in PC, display and keyboard (for example, V-5). It had up to 16 channels that were connected to the central box using cables. Together with MT/AMT, CSAMT methods became very popular with the equipment of this generation.

The fifth generation of multifunction instruments was designed in the end of 1990s and is being used successfully up to the present day in the form of automatic (one switch) and manually managed boxes. Around 4000 boxes of the fifth generation are currently deployed in various parts of the world utilizing MT, AMT, CSAMT, MVP (Ingerov 2011), MulTEM and other geophysical methods.

Current technological advancements in electronic components and computers made the fifth generation instruments lighter, with lower power consumption, better noise protection, and expanded functionality of the instruments to successfully compete with specialized instruments.

MULTIFUNCTION EM RECEIVERS

Multifunction EM receivers GEPARD are shown in Figure 1. They are designed in 4 and 8 channel configurations, both with the same physical dimensions. The receivers have all the parameters of fifth generation instruments:

- Front-end board;
- Analog amplifier;
- 24-bit ADC;
- Signal processor;
- CPU;
- GPS-board;
- Synchronization board;
- Calibration board;
- External media (SD card) board;
- Communication board.

In addition, every channel has a filter board with notches for power frequency and selectable high/low pass filters. In contrast to similar instruments on the market, GEPARDs have flexible, variable sampling rates, which are derivatives of 4 base sampling frequencies. Every channel could be either electrical or magnetic, in any configuration, which allows for effective application of the GEPARD system for both electrical and magnetic methods, depending on the field EM technique. Receiver's data acquisition and parameter schedule could be written to the SD card (convenient for long, repeatable site recordings such as MT, AMT, CSAMT, MVP, etc.) or could be set from the intuitive touchscreen user interface (SP, EP, VES, IP, TDEM, FDEM).

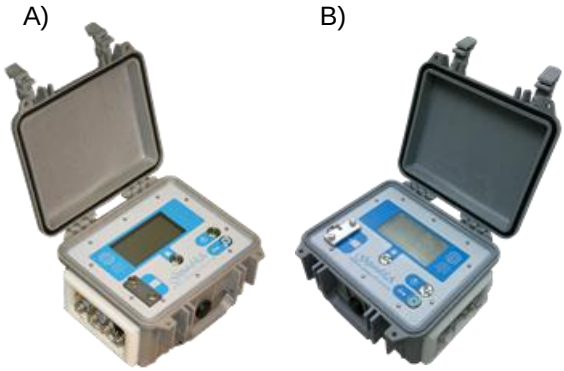

Figure 1. Multifunction geophysical EM receivers; A) 4-channel GEPARD-4A; B) 8-channel GEPARD-8A.

Multifunction geophysical current source AT-100 is shown in Figure 2. It has 100W power output, 0.001 – 1.0A stabilized current with stepping ~1.58. The main feature of the transmitter is the dense row of generated frequencies as the derivatives of 1Hz, 1.22Hz, 1.33Hz, 1.5Hz and 1.66Hz, and the ability to obtain very detailed amplitude and phase curves for CSAMT, CSMT, FDEMS, Spectral IP and others. The change of frequencies can be done manually or a transmit schedule could be recorded to the SD card, specifying the frequency stepping and transmit duration for every frequency in the autonomous operation mode.

Figure 2. Multifunction current source for geophysical EM techniques AT-100.

The eight channel configuration is the most effective in the field. It allows to carry-out data acquisition at two observation sites simultaneously (2E+3H) + (2E + H) for MT/AMT, or four sites for

MVP (H+3H+H+3H) and various configurations for CSAMT. Other option is to use two electric channels and six magnetic for simultaneous recording of the natural EM field in AMT and MT frequency band.

EM FIELD SENSORS AND ACCESSORIES

Magnetic components of an alternating EM field are usually measured with induction coils. For AMT frequency band 50000-5Hz, an AMS-15 sensor is used; for MT frequency band 500-0.0001Hz, an AMS-37 sensor is used. Every coil has a core, copper winding, shield, calibration winding and low-noise wide-band preamplifier. The sensors are connected to the receiver via custom cables. Figure 3 shows AMS-15 and AMS-37 magnetic sensors.

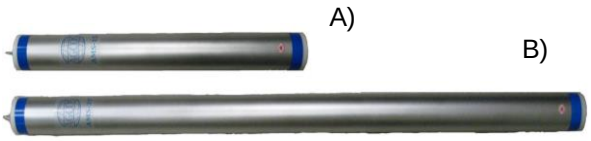

Figure 3. Induction coil magnetic sensors; A) AMS-15, B) AMS-37.

The main feature of the AMS-15/37 magnetic sensors is the field installation with the use of precision field tripods. Tripods could be 1-axis vertical or horizontal, and 3-axis as shown in Figure 4. The 3-axis version is more popular due to the increased productivity in the field, low weight, compact size and the time savings during the installation and removal at the observation site. All tripods can be installed on any terrain, in any climate and during any season.

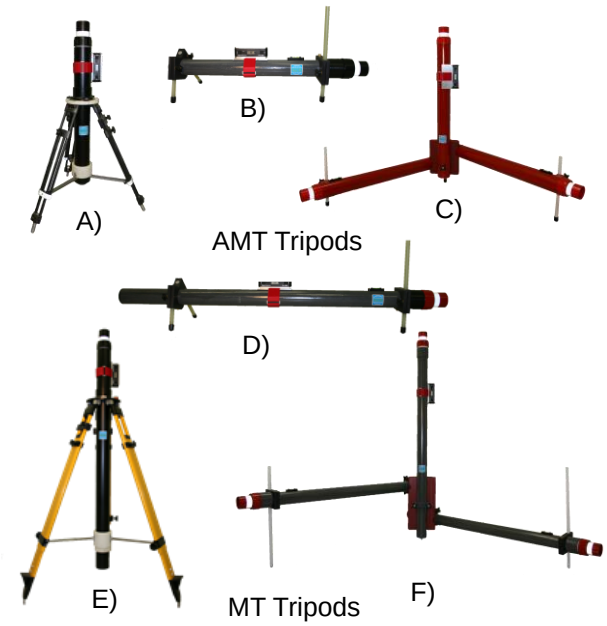

Figure 4. Precision field tripods for induction coil magnetic sensors; A) TRI-1/30; B) TRI-1/30/1; C) TRI-3/30; D) TRI-1/50/1; E)TRI-1/50; F) TRI-3/50.

As for the sensor for the electric components of the EM field, the grounded E-lines (10-100m length) with low-noise, stable, non-polarized electrodes (pots) are used. Depending on the task, electrodes can be copper, lead or silver. Silver electrodes are the most stable and environmentally friendly. All electrodes consist of a hermetic enclosure with a porous membrane, a corresponding metal core and a salt solution. The design of the electrodes includes a unique shape of the porous membrane that effectively increases the contact area with the ground to achieve greater stability and lower grounding contact resistance. Figure 5 shows 3 types of electrodes with the distinct shape of porous membrane.

Figure 5. Low-noise non-polarizing electrodes; A) ACE-84 (copper); B) ALCE-84A (lead); C) ASCE-84AG (silver).

Figure 6. Field application of multifunction EM system.

An example of a detailed field survey with magnetovariational profiling method using 4-channel GEPARD receiver is shown in Figure 6. Field layout consists of three (Hx, Hy, Hz) and one (Hz) magnetic component measurements. The AMT magnetic sensors AMS-15 have been installed in the precision field tripods: 3-axis TRI-3/30 and 1-axis TRI-1/30. Recordings at two nearest sites are done simultaneously. Two field crew members can easily carry one set of equipment from one observation site to the next. In order to increase productivity and to maintain the temperature stability, magnetic sensors are

transported inside the tripods between the observation sites.

CONCLUSION

- Designed and currently manufactured a compact, portable multifunction EM data acquisition system;
- The system allows the realization of all the main geophysical ground EM techniques (with the exception of GeoRadar) in the field;
- The system is composed of EM receivers (4 or 8 channels), transmitter, EM field sensors, accessories and software;
- GEPARD is only one system which allows to carry-out induction (MT, AMT, CSAMT, TEM) and geometrical (VES, DES) soundings productively and economically.
- The system includes 3-axis precision field tripods for induction magnetic sensor installation on any terrain and climate, which not only improves the accuracy, but also significantly increases field work productivity;
- At present time, there is only multifunction geophysical EM data acquisition system that can effectively realize very sensitive and accurate control source EM sounding technique FDEMS;
- At the present time, there is only multifunction geophysical EM data acquisition system that can provide accurate and productive surveys by EM methods using:
  - natural EM field (SP, MT, AMT, MVP, VLF);
  - control source EM field in frequency domain (CSAMT, FDEMS, FDIP, Spectral IP);
  - control source EM field in time domain (LowTEM, MulTEM, TDIP);
  - resistivity (EP, VES, DES, electrotomography);
  - Misse-a-la-Masse.

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