SIP instruments for laboratory testing: current state of the technology and limitations

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Over the last decade the spectral induced polarization (SIP) method has resurged as a promising method for subsurface investigations (Kemna et al. 2012). The SIP method was originally developed for mineral exploration but advances in hardware and theoretical understanding of the IP signals, sources and generation have led to wide applications of the method in environmental and engineering disciplines.

The sensitivity of SIP to bulk and interfacial physicochemical properties permits a wider range of hydrogeophysical and environmental applications, including monitoring of biogeochemical transformations (Atekwana and Slater 2009; Knight et al. 2010). Improvement in hardware, including size and power requirements, along with faster acquisition capabilities and easy access to processing routines is encouraging more widespread adoption of the technique by non-experts. Instrumentation developments focus on resolving small signals to facilitate new applications. This requires accuracy and precision in the experimental set up, but in many cases instrument performance is often overlooked.

Motivated by the remarkably large range of recorded SIP signals on similar materials by different groups, we saw a need for a standardized procedure for SIP set up testing. This work presents our introductory efforts towards this goal, where we compare SIP measurements on different instruments in common used by the scientific community. The experimental samples used were both R-C networks that simulate electrical polarization recorded on earth media properties, and well characterized porous media.

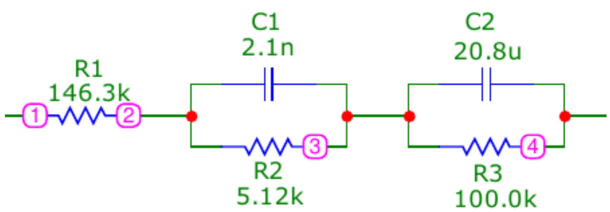

Fig. 1: Generalized schematic of the RC network architecture simulating earth media electrical properties, used for SIP system performance testing (Vanhala and Soininen, 1995).

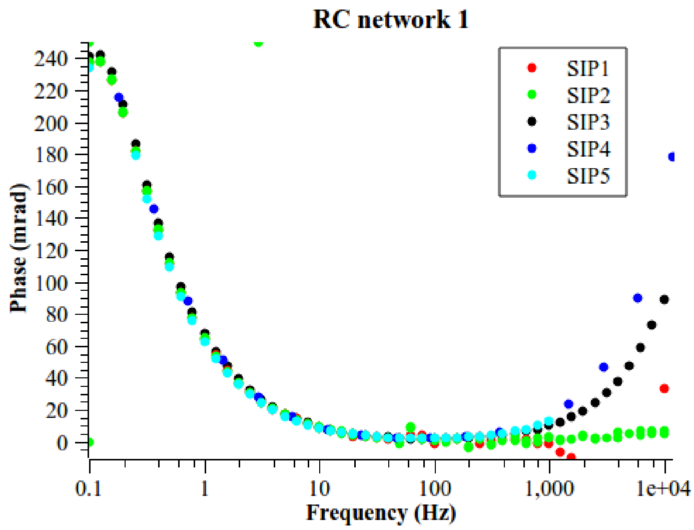

Fig. 2: Characteristic phase response for 5 different SIP systems during preliminary tests with RC network 1 (peak ~ 0.1 Hz)

The first step of the testing procedure involved the use of R-C networks over a wide range of frequencies (1 mHz – 10 kHz). We created a set of four different R-C circuit boxes with different characteristics, one with pure ohmic characteristics and 3 which exhibit phase peaks around 0.1, 1, 10 Hz respectively (Fig. 1). This step permits identification of systematic errors when recording signals typical of real earth materials associated with the experimental set up, without the complexity (e.g. electrode performance) of interfacing with real samples. This step permits measu-rement of the speed of data acquisition in addition to the accuracy of the signal, and the precision of the measurement; during this step we will also evaluate data saving and recovery options after ab-normal measurement termination (e.g. hardware failure, power outage). Preliminary testing showed the RC networks provide a valid means of comparison for different SIP instruments (Fig. 2).

The second step involves the testing of standardized earth media samples. We chose 5 different samples that exhibit different SIP properties (Table 1). All samples are fully saturated with the same fluid (300 µS cm^{-1} KCl) and are permanently sealed in an experimental column specifically designed for this type of testing (Fig. 3). The design of this column allows for high quality SIP measurements (as tested in our laboratory) while allowing for long term use of the sample samples. The latter was very important for the design selected since we envision sharing the standardized samples with other research groups interested in SIP research.

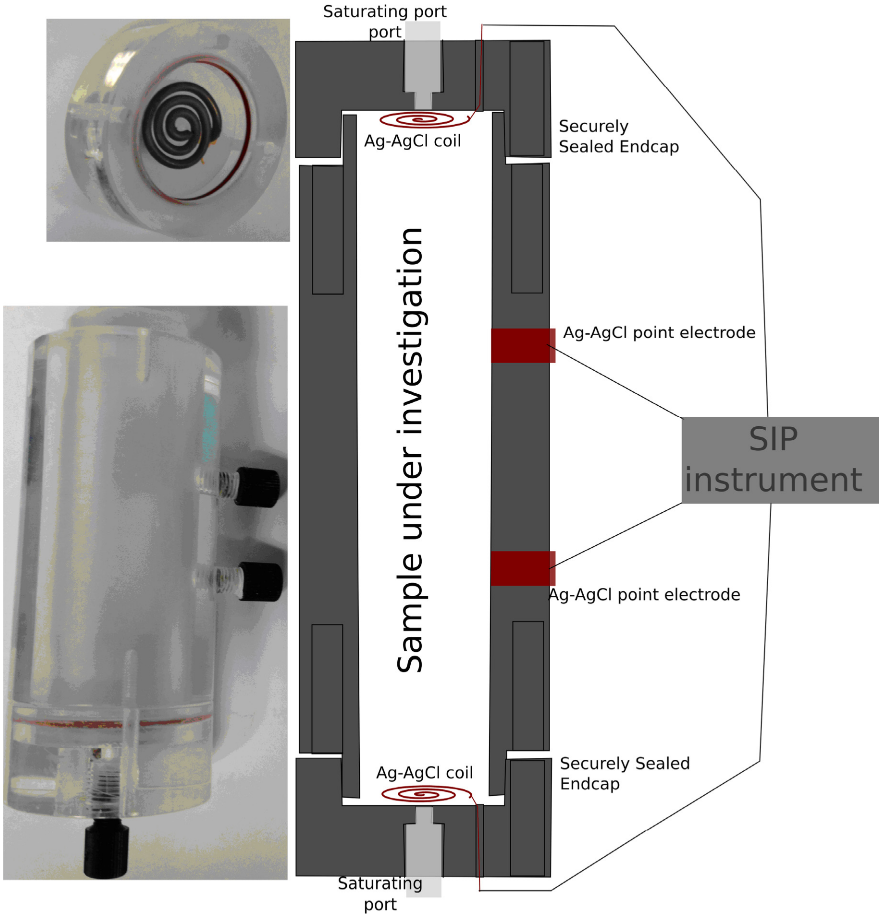

Fig. 3: Schematic and image of the sample holder for the standardized sample testing; after the sample has been packed and saturated, the endcaps are securely and tightly screwed on the main body to minimize any evaporation effects.

Sample	Ottawa Sand	Magnetite	Kaolinite
A	100	0	0
B	98	2	0
C	98	0	5
D	95	5	0
E	93	2	5

Table 1: Composition, by weight, of the five standardized samples.

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