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SIP response to drainage and imbibition: study on correlated random tube networks

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In order to upscale the spectral induced polarization (SIP) response of porous media, from the pore scale to the sample scale, we implement a procedure to compute the macroscopic complex resistivity response of random tube networks. A network is made of a 2D square-meshed grid of connected tubes, which obey to a given tube radius distribution. Once the impedance of each tube is defined (note that it depends on the radius), we solve the conservation law for the electrical charge, to obtain the macroscopic IP response of the network.

We then implement a procedure to simulate the drainage and imbibition in the networks. We compute the resistivity index and the relative permeability of correlated networks at various saturation states, under the assumption that the surface conductivity can be neglected. It appears that these parameters exhibit a hysteretic behaviour, as observed in real media.

Then, we calculate the SIP response of the networks, under the assumption that the electrical impedance of each tube follows a local Warburg conductivity model. We evidence that the shape of the SIP spectra depends on the saturation state. The analysis of the evolution of the macroscopic Cole-Cole parameters of the spectra in function of the saturation also behaves hysteretically, except for the Cole-Cole exponent.

We observe a power-law relationship between the macroscopic DC conductivity and the relative permeability, and also between the time constant and the relative permeability. Moreover, the frequency peak of the phase spectra is directly related to the relative permeability, underlining the potential interest of SIP measurements for the estimation of the permeability of unsaturated media.