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Using the multi-domain Chebyshev spectral method to approximate the electric charge density in 3D resistvity forward modelling problem

A. Kamkar-Rouhani

Shahrood University of Technology, Iran (kamkarr@yahoo.com / Fax: +98 273-3334419 / Phone: +98 273-3335509)

3D resistivity modelling problem established using the integral equation technique, ultimately yields to an electric field-charge density matrix equation that can be written in the simplified matrix form of $E = K.Q$, where E is the electric field intensity, Q is the unknown surface electric charge density and K is the coefficient comprising several other parameters or components. The Chebyshev spectral method which uses Chebyshev polynomials is applied to the 3D problem to approximate the unknown surface charge density on the whole domain. We divide the whole domain into a number of sub-domains (N surface cells). Then the approximation of the unknown quantity Q using a set of Chebyshev polynomials is carried out in each surface cell separately. In this study, for simplicity, we consider a prismatic 3D body in a layered earth though any arbitrarily shaped 3D body can be considered. The grid, which divides the cells, are represented by i, j and k equally spaced points in x, y and z directions, respectively. In each sub-domain (surface cell), we approximate the surface charge density by the same nth degree Chebyshev polynomials. Each surface cell on the prismatic 3D body is perpendicular to one of directions x, y or z. Therefore, the corresponding x, y or z component to that direction everywhere in the surface cell remains constant. The 3-D Chebyshev grid is then applied to simplify the problem, and obtain the surface charge density over each surface cell. For example if a surface cell is perpendicular to z direction, everywhere in the surface cell the z component of the surface cell is constant. and thus, the surface charge density in that surface cell will only be dependent on other two components (e.g., x and y). In other words, the surface charge density for the surface cell will change when one of these two componenets (e.g., x or y) changes. Finally, we can write the surface charge density as a function of r, in which

r is equal to the trigonometric term (i.e. cosine term), and therefor it changes only in the range of [-1,1]. Since the surface charge density is a function piecewise continuous in the interval [-1,1], then it can be written as a sum of a linear combination of the Chebyshev polynomials as functions of r (recited for r) and their coefficients. Based on the orthogonality property of the Chebyshev polynomials with respect to the weight function, the coefficients are computed from an integral relation of the Chebyshev polynomials. The computed coefficients are, then, used in the linear combination to obtain an approximation for the surface charge density.