Plane-wave and flat Earth approximations in EM induction studies

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In electromagnetic sounding methods, such as the magnetotelluric method, studies are usually carried out by treating (1) the inducing field as spatially uniform and (2) the Earth as a semi-infinite conductor with a plane surface. These treatments are both approximations of the electromagnetic induction due to the incidence of a laterally non-uniform inducing field into the conducting spherical Earth. Although the basic theoretical concept was established many decades ago by A.T. Price, L. Cagniard, T. Rikitake, S.P. Srivastava, etc., the physical conditions for these two approximations are not fully and systematically understood, and some confusion appears in the literature. This presentation attempts to re-examine the basic formulation of the electromagnetic induction within the homogeneous conductor in both spherical and Cartesian coordinate systems and to clarify how the conditions for the two approximations were derived in a systematic manner. The result reveals that solutions in the two coordinate systems are consistent with each other at an appropriate limit and that the two approximations result in neither indefinite nor non-unique problems, as suggested in some previous studies, if approximation conditions are properly applied. In addition, a few corrections to related chapters and/or sections of classic papers and textbooks are obtained as a by-product of this research.