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Construction of non-traveling wave solutions from traveling wave solutions of the KdV-type evolution equations

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The famous Korteweg-de Vries (KdV) equation, which arises in many physical contexts, was first introduced as an equation governing weakly nonlinear long shallow water waves when nonlinearity and dispersion are in balance at leading order. If higher order nonlinear and dispersive effects are of interest, then the asymptotic expansion can be extended to the next order in the wave amplitude which leads to the higher order KdV equations. Studying properties of such KdV-type evolution equations commonly starts from assuming the traveling wave (TW) solution form which reduces the problem to an ordinary differential equation (ODE). A variety of direct methods for finding such solutions have been designed but usually there is no algorithmic way to proceed further from this stage. In the present study, a method, which allows constructing non-traveling wave solutions (nTW) of an evolution equation from known TW solutions, is developed and applied to some of the KdV-type equations. The method represents a generalization of a direct method for defining solitary wave solutions of evolution equations which allowed identifying new types of soliton solutions of some KdV-type equations [1]. Applying the generalized method to the classical KdV equation yields the transformation of a new type which converts *one-soliton solutions* of the KdV equation into *two-soliton solutions* of the same equation. Among applications of the method to the higher order KdV equations, an important example of the fifth order integrable dual Sawada–Kotera (SK) [2] and Kaup–Kupershmidt (KK) [3] equations should be mentioned. The method yields transformations from TW solutions of the SK equations to nTW solutions of the KK equation and, vise versa, transformations from TW equations of the KK equations to nTW solutions of the SK equation. Such transformations are found also for the mixed scaling weight KdV-KK and KdV-SK equations, with the KdV flow included, which can arise in physical problems, in particular, in the shallow water wave problem [4] as a result of extending an asymptotic expansion to higher orders. .

References

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