Application of the Singularity Expansion Method (SEM) for Multiconductor Transmission Lines

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Abstract—An equation for the SEM poles of long multiconductor transmission line was formulated on the base of asymptotic approach. The matrix for the reflection coefficients is found by the solution of the EFIE with perturbation theory for thin wires. The analysis of the pole set allows to extract poles corresponding to differential and common current modes.

Keywords - Singularity Expansion Method; MTL.

I. INTRODUCTION

The coupling of high-frequency electromagnetic fields with transmission lines of different nature is one of the main problems of electromagnetic compatibility. Coupling with transmission lines is a special case of interaction of EM fields with scattering objects. For solution of this problem the general Singularity Expansion Method (SEM) was advanced by C.Baum, F. Tesche, D. Giri and other scientists in earlier 1970th [1]. The positions of poles of the response function (SEM poles) are a unique characteristic of the system and do not dependent on the kind of excitation and position of the current measurement point, The SEM expansion defines the response both in frequency and time domain, radiation of the system, its scattering amplitude, etc.

The method was applied for the case of high-frequency coupling with long transmission lines in [2,3] with the so called asymptotic approach [4], where the SEM poles are defined as roots of the resonant denominator containing high frequency reflection coefficients for TEM current waves. In particular, for the thin wire line, these coefficient can be obtained by the iteration solution of the EFIE [4].

II. METHOD AND RESULTS

In the present paper we generalized the SEM method for multiconductor lines. The asymptotic approach for the long multiconductor line excited by a plane wave was developed in [5]. In this approach the current near the terminals has a complex structure, containing TEM modes, leaky modes, and radiation modes. However, far from the terminals, in the so called asymptotic region the current has a simple structure: it consists of forward and backward running TEM waves and the solution for the current for the case of infinite wire.

The matrix of coefficients for the TEM waves contains, in particular, the inverse matrix of "resonance denominator", which, in turn, includes matrices of reflection coefficients of TEM current waves from the left and right terminals and the diagonal matrix of the exponential propagator. The required matrix of reflection coefficient can be found with the iteration approach for the EFIE. Assuming that the determinant of the denominator matrix is an analytic function of the complex frequency, we can find its zeros by one way or another, which yields the SEM poles. Note, that there are cases when it is not an analytic function and one such case was treated by Giri and Teshe [7] for antenna in a conducting medium. In this case an additional brunch cut appears, which effect requires additional consideration.

A case of multiconductor open-circuit horizontal line was considered. For such line the elements of reflection coefficient matrix can be obtained in explicit form using the integral exponent function. For the simplest case of two parallel lines with equal height we investigated poles in dependence of distance between the lines. When the distance is essentially larger than the height of the line, the poles do not differ from the single line case, but with small splitting. As the distance between the wires decreases, the splitting increases. When the wires are close to each other, one can observe two sets of SEM poles. One set of poles corresponds to the differential current mode with small imaginary part and the second set of SEM poles corresponds to the common current mode, with large imaginary part (antenna regime).

The results were compared with the one obtained by NEC code with complex frequency and contour integration in complex ω-plane [6] and an excellent agreement was found.

REFERENCES

[1] C.E.Baum, *The Singularity Expansion Method in Electromagnetics*, Edited by D.V.Giri and F.M. Tesche, Lulu Enterprices, 2012.

[2] S.V.Tkachenko, J.Nitsch, R.Vick, F.Rachidi, D.Poljak, “Singularity expansion method (SEM) for long terminated transmission lines”, *2013 Int. Conf. on Electromagnetics in Advanced Applications* (ICEAA), Torino, 9-13 Sept. 2013.

[3] F.Middelstaedt, S.V.Tkachenko, R.Rambousky, and R.Vick, "High-Frequency Electromagnetic Field Coupling to a Long, Finite Wire with Vertical Risers Above Ground", *IEEE Trans. on EMC*, Vol. **58**,No.4, 2016, pp.1169-1175.

[4] F.Rachidi and S.Tkachenko, ed., *Electromagnetic Field Interaction with Transmission Lines: From Classical Theory to HF Radiation Effects*, WIT Press 2008.

[5] G.Lugrin, S.V.Tkachenko, F.Rachidi, M.Rubinstein, R.Cherkaoui, "High-Frequency Electromagnetic Coupling to Multiconductor Transmission Lines of Finite Length", *IEEE Trans. on EMC* ,Vol. **57**, N 6, 2015, pp. 1714-1723.

[6] B.K.Singaraju, D.V.Giri and C.E. Baum, "Further Development in the Application of Contour Integration to the Evaluation of the Zeros of Analytic Functions and Relevant Computer Programs", *Mathematical Notes*, Note 42, March 1976.

[7] D.V.Giri, F.M. Tesche, "On the Use of Singularity Expansion Method for Analysis of Antennas in Conducting Media", *Electromagnetics* V. 1, Nr. 4, pp.455-471, 1981.