Intermodulation Analysis by Spice-Oriented Harmonic Balance Method

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SUMMARY

Frequency-domain analysis of nonlinear electronic circuits excited by multiple frequency inputs is very important for designing integrated circuits and communication systems. Volterra series methods are widely used for the analysis [1–3] because they give the solutions in analytical forms. The algorithms are based on bilinear theorem [1], and they can be effectively applied to the intermodulation analysis, where nonlinear elements must be described by the polynomial functions.

HB (harmonic balance) method is also well-known in the frequency-domain analysis, which will give good results even for relatively strong nonlinear circuits. The classical HB methods [4–6] have been applied to relatively small scale circuits and found many interesting nonlinear phenomena such as bifurcations and chaos. In the HB method, nonlinear elements must be also described by polynomial functions to obtain the Fourier coefficients. Therefore, the applications of HB method to large scale circuits is complicated task. For example, if the circuit equation has “n” of polynomial functions and “K” of frequency components are considered in the analysis, then the dimension of determining equation is “$n(2K+1)$”.

In this paper, we propose *Spice-oriented HB method combining with MATLAB*. Firstly, the nonlinear elements such as bipolar transistors and MOS FET are modeled by the exponential function. Then the functions are approximated by the Taylor series in the polynomial forms. The input-output relation of Fourier coefficients for the polynomial function can be obtained in the symbolic forms with the use of MATLAB, and then modeled by ABMs (Analog Behavior Models) of Spice. Therefore, it is further possible to formulate the determining equation of HB method in the schematic form or net-list of Spice. It can be easily solved by DC analysis of Spice, and we can get the frequency-domain solutions, efficiently. Our HB method requires no troublesome tasks such as formulation of the circuit equations and many transformations required to get the determining equation.

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