Spice-Oriented Frequency Domain Analysis Combining with MATLAB

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SUMMARY

For designing integrated circuits and communication systems, it is very important to obtain the frequency-domain characteristics of nonlinear circuits. There are two kinds of the time-domain and frequency-domain methods. Although, first one can get the accurate steady-state waveform, it is unsuitable to calculate the frequency response curve [1,2]. The latter is useful to obtain the frequency response curve of nonlinear circuits. There are two methods of Volterra series and harmonic balance. The Volterra series method is widely used for the purposes [3-5] which gives the solution in analytical forms. The algorithms are based on bilinear theorem, and can be also effectively applied to the intermodulation's analysis driven by multiple inputs. However, they can be applied to only weakly nonlinear circuits, and the solutions of the strong nonlinear circuits become erroneous.

The harmonic balance (HB) is also a well-known method for the frequency domain analysis, which gives good results even for relatively strong nonlinear circuits. There are two types of classical HB [6-8] and computer-aided HB methods [9,10]. The classical HB can be applied to relatively small scale circuits, but they have found many interesting nonlinear phenomena such as bifurcations and chaos. The computer-aided HBs are rather numerical methods, which are applied to every nodal equation. Therefore, the determining equations usually become very large and are solved by iteration manners such as the Newton and/or relaxation methods. We propose here another type of Spice-oriented HB method which ideas are based on the classical HB. However, combining MATLAB and Spice, it is largely improved such that it can be easily applied to large scale nonlinear circuits, where the determining equation called *Sine-Cosine circuit* [11,12] can be given in the form of schematic and/or net-list of Spice. The circuit can be solved by DC analysis of Spice simulator and the frequency characteristics are easily obtained.

REFERENCES

[1] T.J.Aprille and T.N.Trick "Steady-state analysis of nonlinear circuits with periodic input, *Proc. IEEE*, Vol.60,pp.108-114, 1972.
[2] R.Telichevesky and K.Kundert, *SpectreRF Primer,*, Cadence Design Systems, San Jose, Ca. 1996.
[3] M.Schetzen, *The Volterra and Wiener Theorems of Nonlinear Systems*, John Wiley and Sons, 1978.
[4] J.Wood and D.E.Root, *Fundamentals of Nonlinear Behavioral Modeling for RF and Microwave Design*, Artech House, 2005.
[5] P.Wambacq and W.Sansen, *Distortion Analysis of Analog Integrated Circuits*, Kluwer Academic Pub., 1998.
[6] C.Hayashi, *Nonlinear Oscillations in Physical Systems*, McGraw-Hill, 1964.
[7] Y.Ueda, *The Road to Chaos-II*, Aerial Press. Inc., 2001.
[8] R.J.Gilmore and M.B.Steer, "Nonlinear circuit analysis using the method of harmonic balance-A review of the Art.
[9] R.Telichevesky, K.S.Kundart and J.K.White, "Efficient steady-state analysis based on matrix-free Krylov-subspace methods," *ACM*, pp.480-485, 1995.
[10] A.Ushida, Y.Yamagami and Y.Nishio, "Frequency responses of nonlinear networks using curve tracing algorithm,"*ISCAS 2002*, vol.I, pp.641-644, 2002.
[11] J.Kawata, Y.Taniguchi, M.Oda,Y.Yamagami, Y.Nishio and A.Ushida, " Spice-oriented frequency-domain analysis of nonlinear electronic circuits," *IEICE Trans. Fundamentals*, Vol.E90-A, 2007.
[12] A.Ushida, Y.Yamagami and Y.Nishio, "Frequency response of nonlinear networks using curve tracing algorithm," *ISCAS 2002*, vol.1, pp.641-644, 2002.