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Spice-Oriented Envelope Analysis Using Harmonic Balance Method

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1. Introduction

For designing integrated circuits and communication systems, it is very important to analyze the frequency-domain characteristics of nonlinear circuits. Many of these systems consist of strong nonlinear circuits. In this study, we analyze a base modulation circuit using Spice-oriented Harmonic Balance (HB) method. The HB method is the technique that Fourier coefficients can be obtained in symbolic forms by using MATLAB. The determining equation of HB circuit is given by the net-lists, which can be solved by the DC analysis of Spice. Thus, we can obtain a good solution for the strong nonlinear systems.

2. Envelope analysis

Envelope analysis is important for tracing a signal before modulated. Now, we consider a base modulation circuit driven by two inputs as shown in Fig. 1.

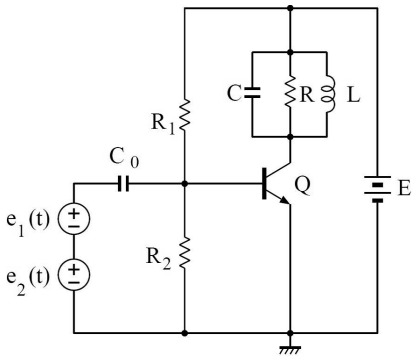


Fig. 1 Base modulation circuit.

R_1=50 [kΩ], R_2=10 [kΩ], R=1 [kΩ], C=C_0=1 [nF], L=10 [μH], E=10 [V], e_1(t)=$E_1 \sin\omega_1 t$, e_2(t)=$E_2 \sin\omega_2 t$, E_1=E_2=0.005[V], ω_1=10[MHz] ω_2=9[MHz].
We assume e_1 is carrier wave and e_2 is signal wave, so the input is described as

$e(t) = E_1 \cos\omega_1 t + E_2 \cos\omega_2 t.$

And we assume $\omega_2 = \omega_1 + \Delta\omega$, the input is transformed to

$$\begin{aligned} e(t) &= E_1 \cos\omega_1 t + E_2 \cos(\omega_1 + \Delta\omega)t \\ &= (E_1 + E_2 \cos\Delta\omega t)\cos\omega_1 t - (E_2 \sin\Delta\omega t)\sin\omega_1 t \\ &= A(t)\cos\omega_1 t + B(t)\sin\omega_1 t \qquad (1) \end{aligned}$$

$$for \begin{cases} A(t) = E_1 + E_2 \cos\Delta\omega t \\ B(t) = -E_2 \sin\Delta\omega t \end{cases}$$

So, we can obtain amplitude modulating signal with slowly changing coefficients $A(t)$ and $B(t)$.

We assume the inductor current i_C and the capacitor voltage v_L as follows

$$i_L(t) = I_C(t)\cos\omega_C t + I_S(t)\sin\omega_C t \qquad (2.1)$$

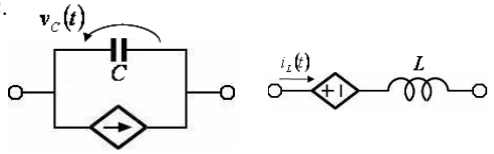
$$v_C(t) = V_C(t)\cos\omega_C t + V_S(t)\sin\omega_c t \qquad (2.2)$$

Hence, the inductor voltage v_L and the capacitor current i_C are given by

$$\begin{aligned} v_L = L\frac{di_L}{dt} &= \omega_C L I_S(t)\cos\omega_C t - \omega_C L I_C \sin\omega_C t \\ &\quad + L\frac{dI_C}{dt}\cos\omega_C t + L\frac{dI_S}{dt}\sin\omega_C t \quad (3.1) \end{aligned}$$

$$\begin{aligned} i_C(t) = C\frac{dv_C}{dt} &= \omega_C C V_S(t)\cos\omega_C t - \omega_C C V I_C \sin\omega_C t \\ &\quad + C\frac{dV_C}{dt}\cos\omega_C t + C\frac{dV_S}{dt}\sin\omega_C t \quad (3.2) \end{aligned}$$

Therefore, we have the elements for envelope analysis as Fig. 2.



(a)capacitor (b)inductor

Fig. 2 Envelope circuits.

We make the Sine-Cosine circuit that is equivalent to the HB determining equation[2]. Thus, the circuit can be solved by Spice, and the envelope is obtained.

3. Simulation result

We show the simulation result in Fig. 3. And we can obtain the envelope of the signal (1), which is almost equal to the transient analysis result.

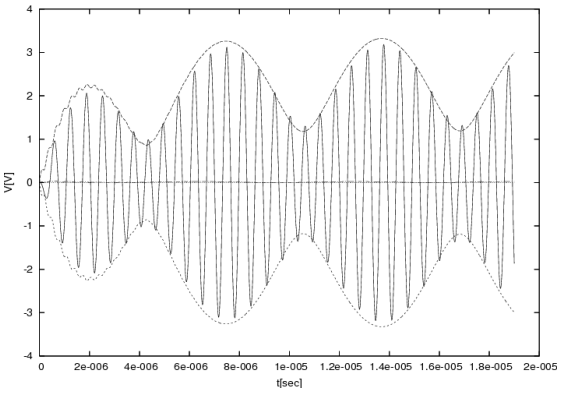


Fig. 3 Simulation result.

4. Conclusions and remarks

In this study, we proposed a method for envelope analysis based on Spice-oriented HB method. This method could efficiently trace the envelope curves of amplitude modulation circuit.

References

[1] A. Ushida, Y. Yamagami and Y. Nishio, "Frequency Responses of Nonlinear Networks Using Curve Tracing algorithm," Proc. of ISCAS'02, vol.I, pp.641-644, 2002.

[2] T. Kinouchi, Y. Yamagami, Y. Nishio, J. Kawata, and A. Ushida, "Spice-Oriented Harmonic Balance and Volterra Series Methods," Proc. of NOLTA'07, pp.513-516, 2007.