A Physical model of the C_{BC} for the linearity characterisitics of AlGaAs/GaAs HBTs

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It is commonly known that C_{BC} is a very strong nonlinear source of HBT and should be linearized to reduce the third-order intermodulation (IM) distortion of HBT [1-2]. However, the IP3 behaviors of HBTs are studied only at a small signal range. To investigate the contribution of the nonlinear C_{BC} for the distortion at a large signal range, we have developed an analytical nonlinear HBT model in a commercially available harmonic balance simulator, ADS using symbolically defined devices (SDD's).

Fig. 1 shows the nonlinear equivalent circuit for the analysis. In the figure, R_e, R_{b1}, and R_{b2} are linear components calculated from HBTs structure while I_{ee}, I_{cc}, C_{be}, C_{bci}, and C_{bcx} are bias dependent nonlinear components. The current model is based on the thermionic-diffusion model. Self-heating effects are also considered. The Kirk effect has not been observed in any POSTECH HBTs and the effect is precluded from the model. The C_{BC} is modeled carefully. The model includes the effect of the ionized donor charge compensated by the mobile charge injected to the depleted collector region. C_{BC} is therefore dependent not only on base-collector voltage but also collector current.

Harmonic balance simulations based on the present model are performed at 2 GHz. The Input and output are matched for the maximum gain and output power, respectively. The HBTs with the same epi structures except collector's thickness are simulated for the comparison. The HBT with the punch-through collector has a 0.4 μm-thick collector doped to 2×10^{16} cm^{-3} and the HBT with the normal collector has a 1 μm-thick collector. The punch-throughed HBT has a fully depleted collector even at V_{CE} = 1.5 V and Ic = 0. It's C_{BC} is therefore constant for whole current range at V_{CE} =3.5 V. On the contrary, the C_{BC} of the normal HBT has the nonlinear characteristics for V_{CE} and I_C. Two-tone test results of the fabricated HBTs, which have 32 unit cells of 2×11 μm^2 emitter fingers are shown in Fig. 2. At a low input signal, the HBT with punch-throughed collector has much lower IM3 than the normal HBT because the normal HBT's C_{BC} is highly nonlinear. As an input power level increases, the IM3 of the normal HBT grows at a lot slower pace than the normal 3:1 slope of the input signal level. At an extremely large signal range, IM3 signal is dominantly generated by the current cut-off characteristics rather than the nonlinear C_{BC}. Before the cut-off region, the nonlinear behaviors could be explained using our injection charge dependent C_{BC} model.

[1] J.W. Lee, et. al, "Intermodulation Mechanism and Linearization of AlGaAs/GaAs HBT's," *IEEE Trans. on MTT*, Vol. 45, No. 12, Dec. 1997, pp. 2065-2072.
[2] K.W. Kobayashi, et. al., "A 44-GHz-High IP3 HBT MMIC Amplifier for Low DC Power Millimeter-Wave Receiver Applications," *IEEE journal of Solid-State Circuits,* Vol. 34, No. 9, 1999, p. 1188-1194.

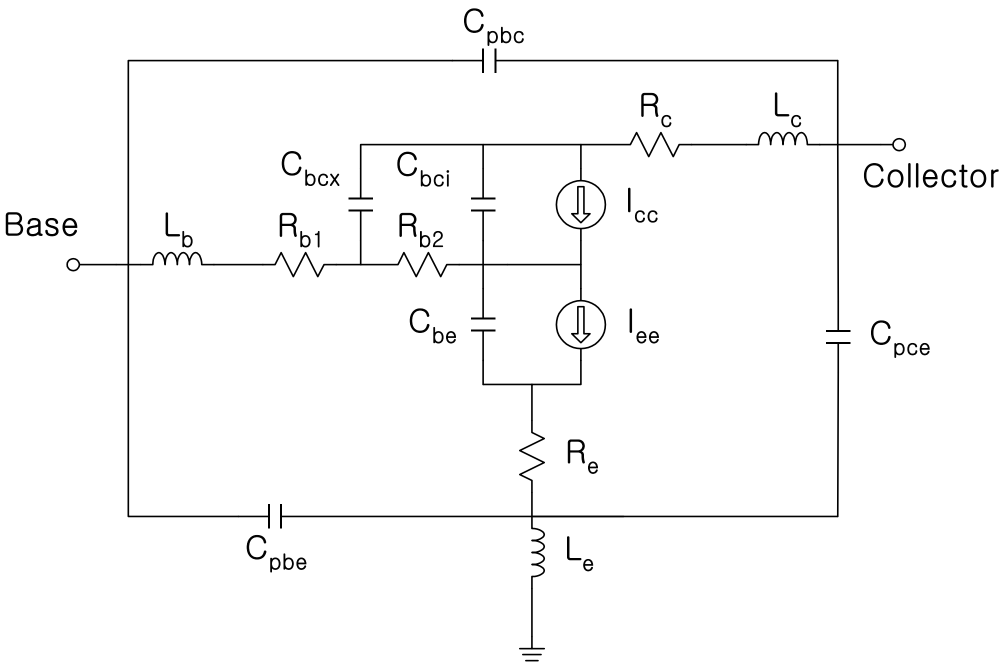

Fig. 1. The nonlinear HBT circuit

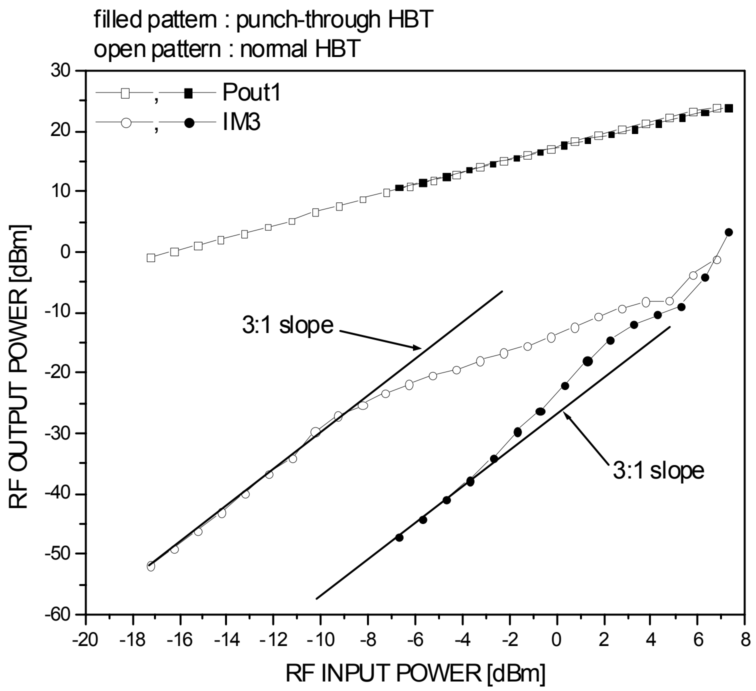

Fig. 2. The two-tone test results of the fabricated power HBTs.