Resonance Phase Operation of Transistors Beyond the Transit Frequency

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Decades of successful microelectronics development are based on the known transistor paradigm offering a broad band current gain β up to the transit frequency f_T

$$\beta = \beta_0/[1 + j(f/f_T)] \quad (1)$$

For very high frequencies $f >> f_T/\beta_0$, Eq. (1) simplifies to

$$\beta \cong -j(f_T/f) \quad (2)$$

which shows the phase delay (π/2) of the output current as well as the amplitude decrease to β = 1 when operation frequency f reaches f_T. In the usual logarithmic plot of gain β *vs.* frequency f one will find a 20 dB gain decay per frequency decade.

Consequently, device engineers worked hard to reduce phase delays and to recover current gains at high f. With device dimensions approaching 100 nm and vertical hetero-structures, impressive results in III-V and SiGe/Si were obtained, e.g. 350 GHz f_T for a SiGe-HBT.[1]

But remember early knowledge of networks which states that a specific value (π) of phase delay between voltage and current (negative differential resistance) is valuable for amplification and oscillation. This large phase delay may be utilized to operate transistors at a resonance frequency (Fig. 1) beyond the transit frequency.[2]

Our first experimental results with a SiGe-HBT as injector and a silicon depletion layer as drift region seem to confirm the concept. The phase delay is composed of the contributions from coherent transport[3] through the depletion region. Possible injection mechanisms for oscillators up to the THz regime will be discussed.

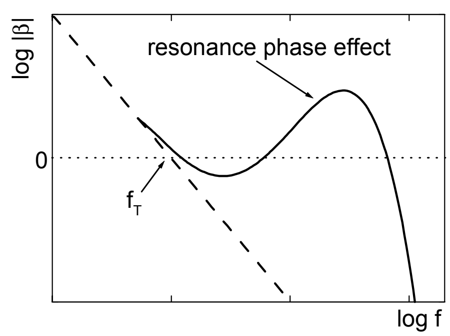

FIG. 1: Current gain |β| *vs.* frequency f at and beyond the transit frequency f_T.

[1] J. Eberhardt and E. Kasper, Solid State Electronics **45**, 2097 (2001).

[2] H. Jorke, M. Schäfer, and J. F. Luy, in: *Proc. 2001 Topical Meeting Si Monolithic Integ, Circ. RF Systems*, IEEE 2001, pp.149-156

[3] S. Luryi, in: *Proc. ISDRS*, Vol 1 (1993), pp. 59-64.