

# **Self-consistent Transit time determination from transit frequency**

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## Basic equations

- relation between transit frequency and transit time:  $\frac{1}{2\pi f_T} = \tau_f + \left( r_{Cx} + r_E + \frac{r_B}{\beta_0} \right) C_{BC} + \frac{\Sigma C_B}{g_m}$

- assume 1D case for illustrating assumptions and possible issues:  $\frac{1}{2\pi f_T} = \tau_f + \frac{C_{jEi} + C_{jCi}}{g_m}$

- major factors affecting accurate determination of  $\tau_f$  at medium and low current densities:

- transconductance  $g_m = \frac{I_C}{m_C(I_C)V_T}$

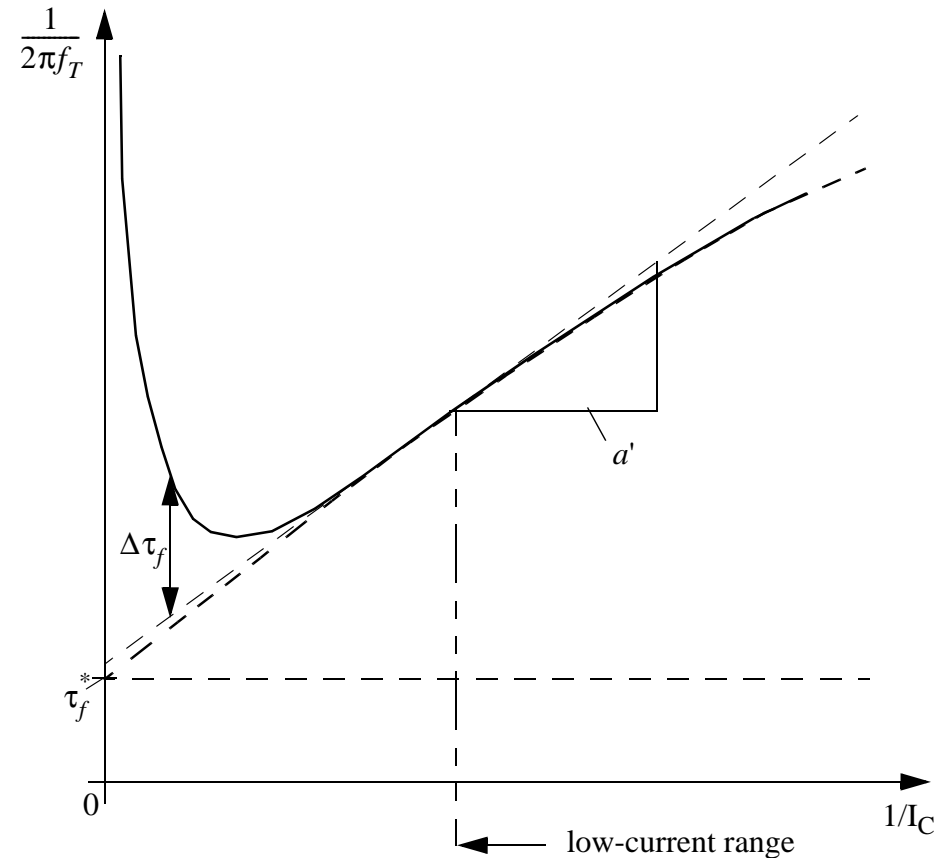
- BE and BC depletion capacitances  $C_{jEi}$  and  $C_{jCi}$

- split  $\tau_f$  into low and high current portion  $\frac{1}{2\pi f_T} = \tau_{f0} + \Delta\tau_f + \frac{C_{jEi} + C_{jCi}}{I_C} m_C V_T$

- at sufficiently low current densities  $\frac{1}{2\pi f_T} = \tau_{f0} + a' \frac{1}{I_C}$  with  $a' = (C_{jEi} + C_{jCi}) m_C V_T$

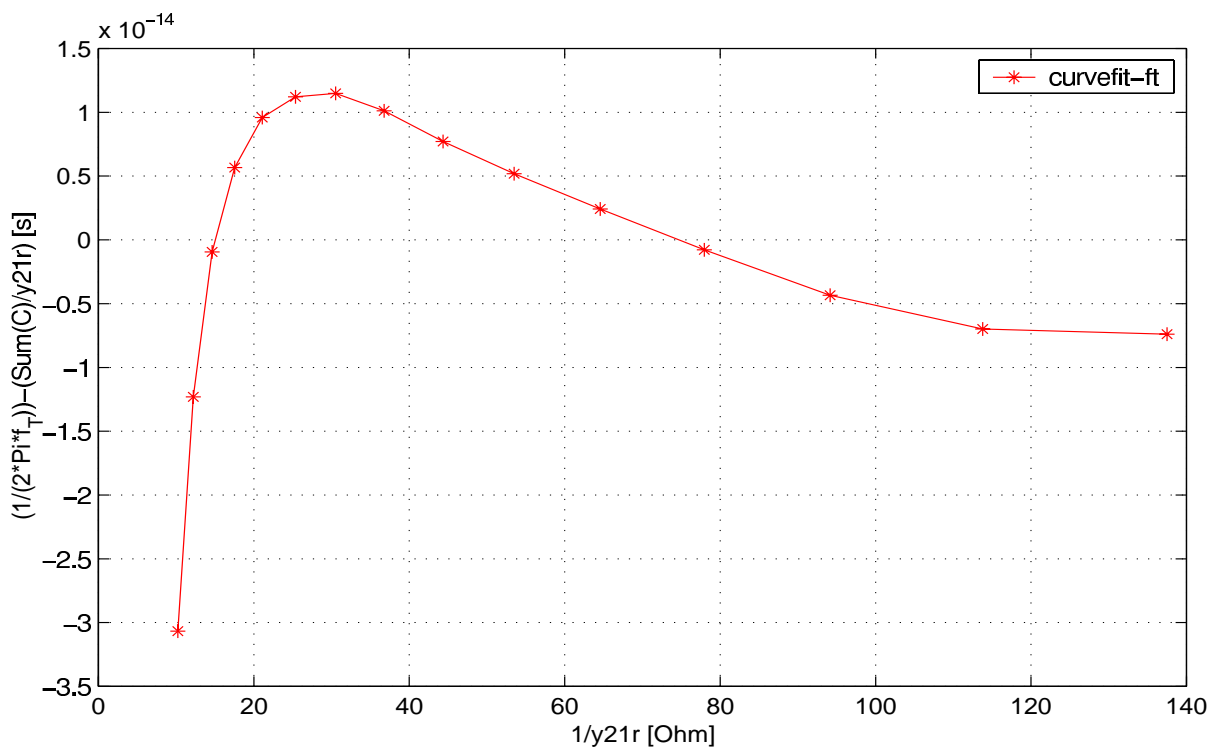
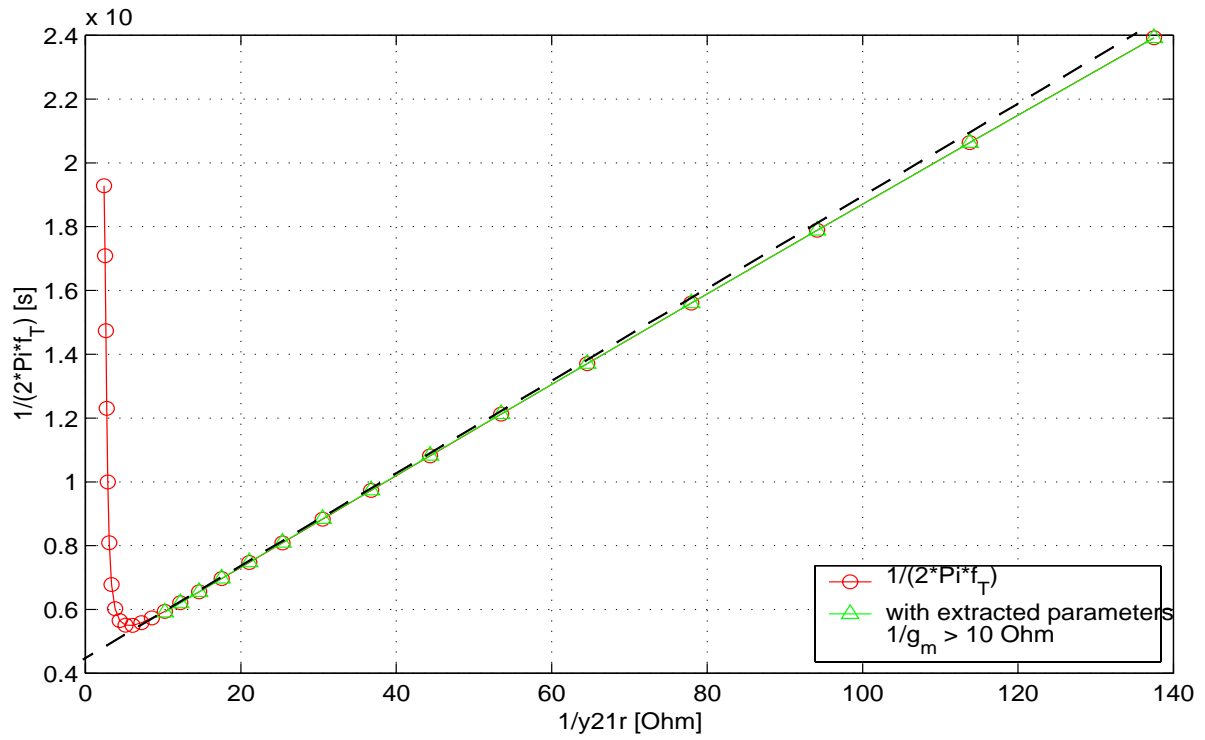
## The standard method

- constant slope not always easy to find  
=> ambiguity regarding  $\tau_f$  determination
- caused by current dependence of
  - ideality factor  $m_C$
  - BE depletion capacitance
  - Note: bias dependence of BC depletion capacitance can be eliminated by measuring at  $V_{BC} = \text{const}$
- inconsistent with model that (accurately) describes above variables  
(although error often very small)



**... has its shortcomings**

# Improved method



## Comments

### Accuracy considerations

- upper transconductance (or current) limit:  $\frac{1}{g_m} \geq \frac{1}{g_m}$  (inflection point)
- example (conventional 25GHz process):

model parameters	original	set 1 $\min(1/g_m)=10\Omega$	set 2 $\min(1/g_m)=20\Omega$	standard method
$\tau_{f0} \cdot [\text{ps}]$	4.371	4.3825 (0.26%)	4.397 (0.59%)	4.483 (2.6%)
$a_{jEi} = \hat{C}_{jEi}/C_{jEi0}$	2.5	2.8455 (13.8%)	2.486 (0.56%)	2.712 (8.5%)

- for Sige HBTs the standard method seems to give larger deviations

### Alternative(s)

- standard method: need to model  $m_C(I_C)$  or use table values from measurements