L2.1-2: Improving Traveling-Wave Tubes for Modulated Operation in Back-Off

Djamschid Safi[1], Philip Birtel[2], Arne F. Jacob[1]

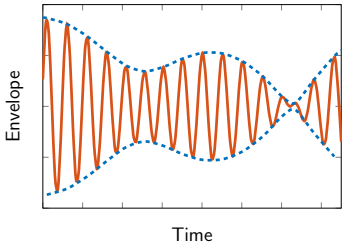
[1]Technische Universität Hamburg, Institut für Hochfrequenztechnik, Germany
[2]Thales Electronic Systems, Ulm, Germany

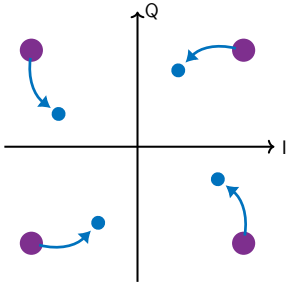
6th ITG International Vacuum Electronics Workshop 2018, Bad Honnef
Session 2.1: Traveling Wave Tubes (TWTs) - September 7, 2018

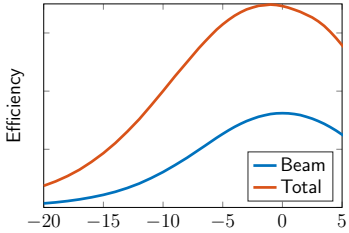
TUHH THALES

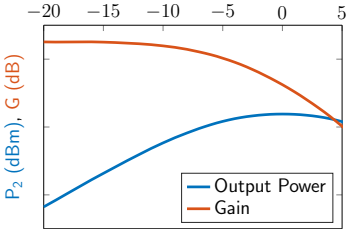
Outline

Motivation: Why is CW not enough?

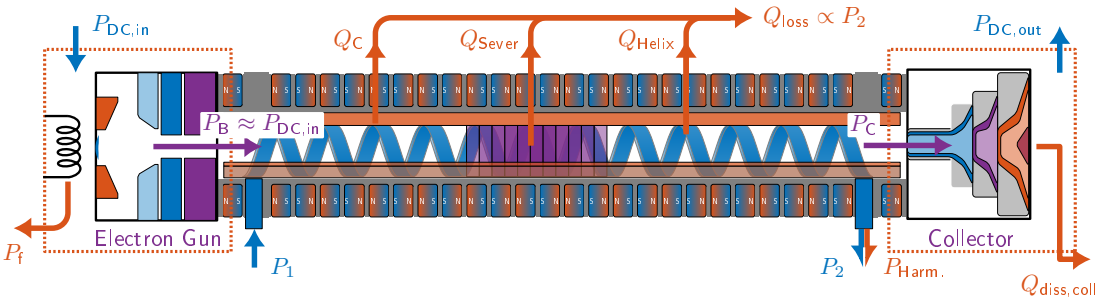








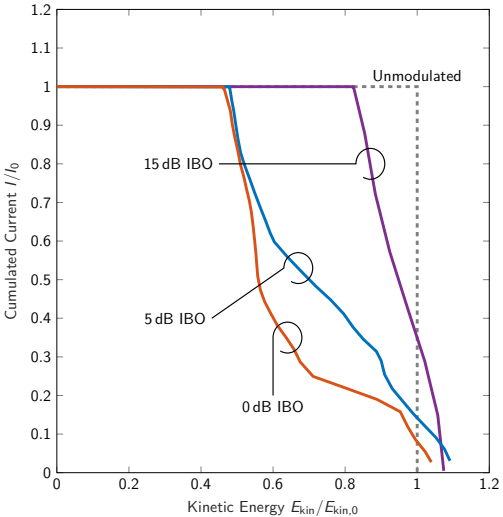
Power Flow and Efficiency Definitions.

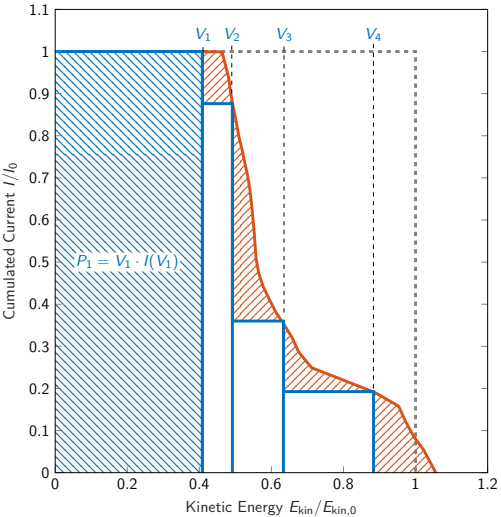


Efficiency Definitions.

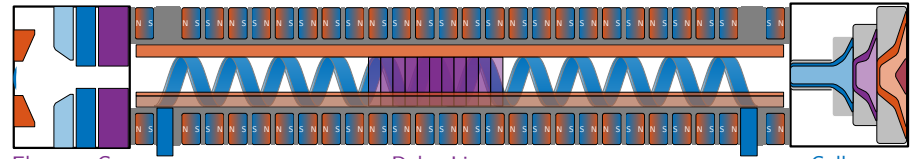
$$\eta_B = \frac{P_2}{P_B}, \qquad \eta_C = \frac{P_{DC,out}}{P_C}, \qquad \eta_{total} = \frac{P_2}{P_{DC,in} - P_{DC,out}}$$

Electron Velocity Spectrum.





Approaches.



- Saturated input / output power
- Nonlinear phase
- Small-signal gain and compression
- Frequency flatness and symmetry
- Collector efficiency
- Beam efficiency
- Distortion

Outline

TUHH

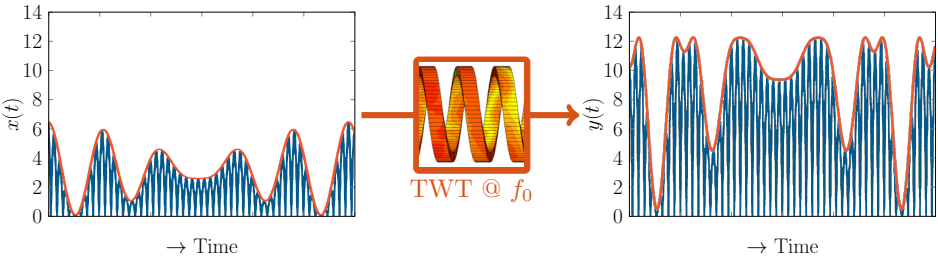
Envelope Method - Starting Point.

TUHH

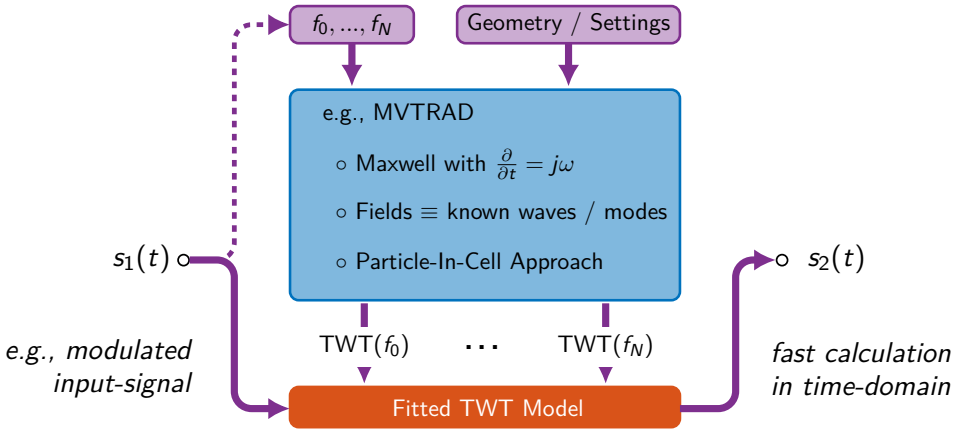
- Assumption 1: modulation time significantly larger than TWT time constants
- Assumption 2: dispersion of the delay line is low

→ Break down TWT to complex transfer function

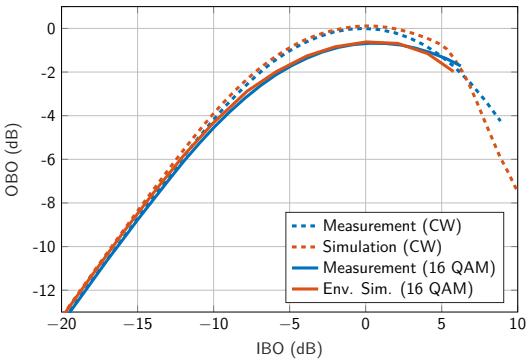
→ Fast time-domain calculation

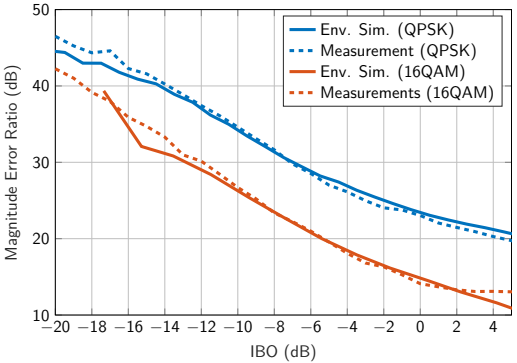


Envelope Method.



Envelope Simulation vs. Measurements.

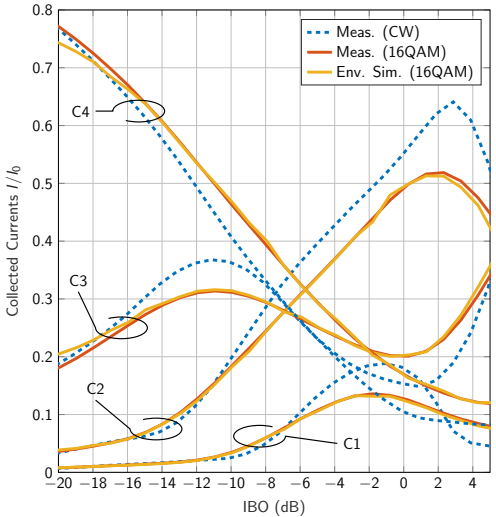


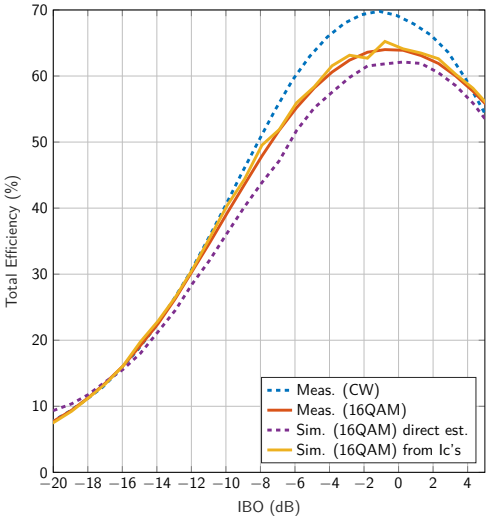


$$\mathrm{MER} = 10 \log_{10} \left(\frac{P_{\text{reference}}}{P_{\text{error}}} \right) \quad [\mathrm{dB}]$$

(MER = Modulation Error Ratio, related to error vector magnitude)

Estimation - Beam Power and Total Efficiency.



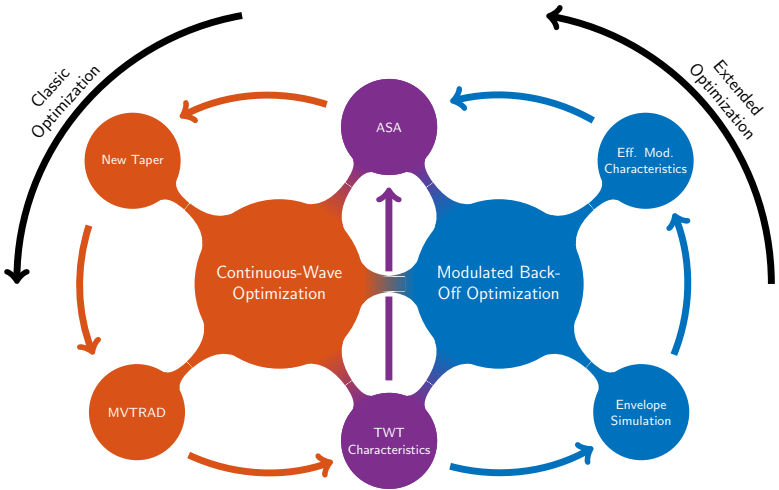


Outline

TUHH

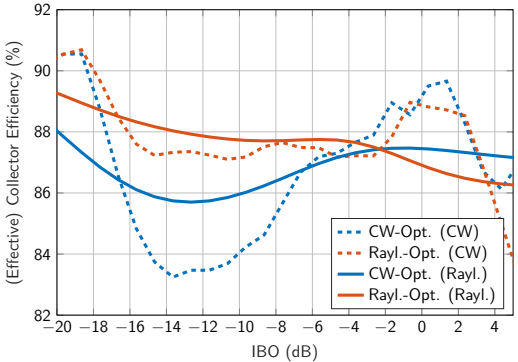
Optimization Workflow with Adaptive Simulated Annealing (ASA).

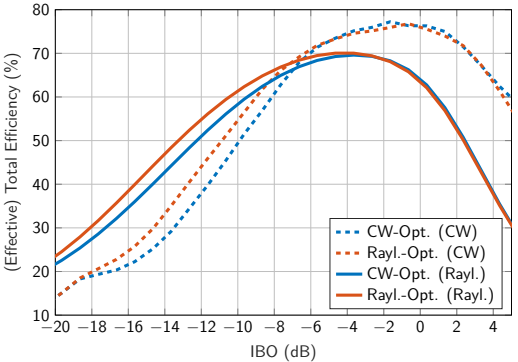
TUHH



CW-Optimization vs. Rayleigh-Optimization (Modulated Signals).

TUHH

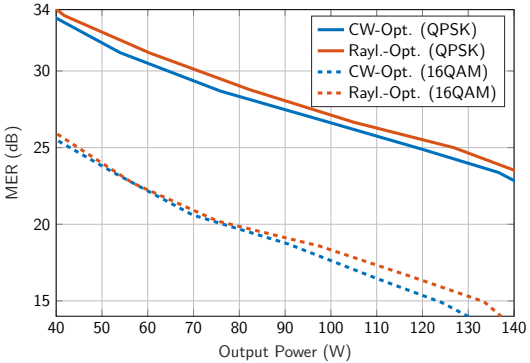


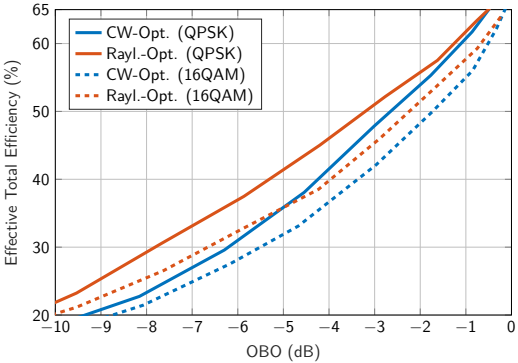


- - continuous-wave operation (CW)
— modulated operation (Rayl.)

— Classical Optimization (CW)
— Extended Optimization (Rayl.)

Comparison: Other Modulations.





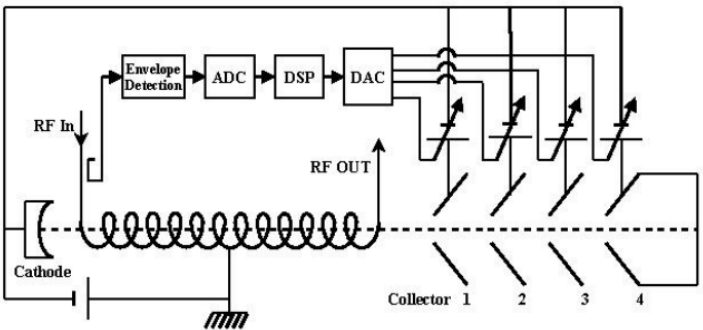
$$\mathrm{MER} = 10 \log_{10} \left(\frac{P_{\text{reference}}}{P_{\text{error}}} \right) \quad [\mathrm{dB}]$$

(MER = Modulation Error Ratio, related to error vector magnitude)

Outline

TUHH

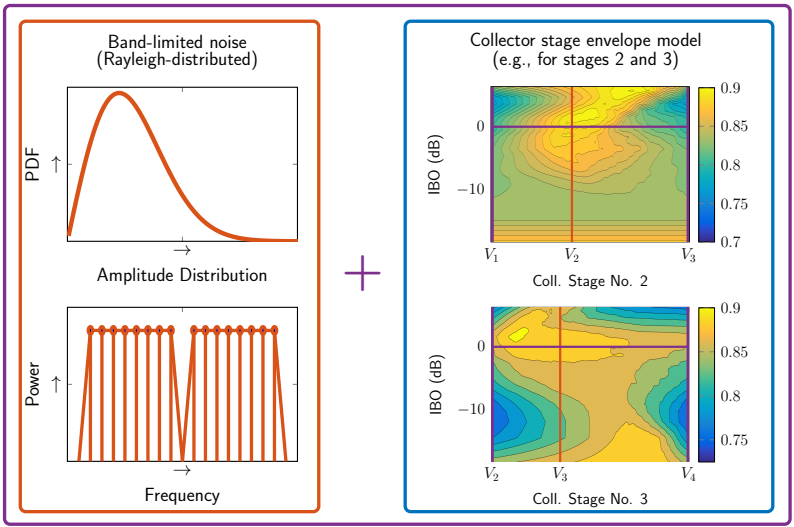
Dynamic Collector: Idea.



[1]

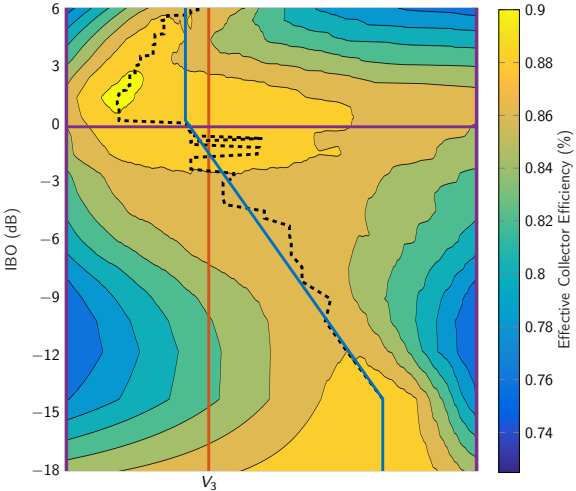
[1] J. X. Qiu, D. K. Abe, T. M. Antonsen, B. G. Danly, B. Levush and R. E. Myers, "Efficient Operation of Traveling-Wave Tube Amplifier with Dynamically Adjusted Collector Bias Voltages." *In: 2007 IEEE/MTT-S International Microwave Symposium, Honolulu, HI, pp. 1267-1270, 2007.*

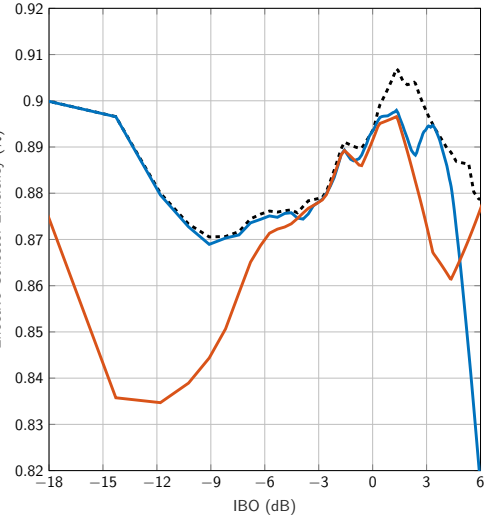
Simulation Setting.



$\approx \eta_{\text{Coll.}}$ (effective)

Simulation Study.





Outline

TUHH

Summary and Prospects.

TUHH

Summary

- BO-efficiency is important for modulated operation.
- Envelope simulation is a useful tool to evaluate the TWT's multi-tone behavior.
- Delay-line optimization improves efficiency and nonlinear distortions.
- Idea of dynamic collectors is promising.

Outlook

- Patterns and design-rules for delay-line.
- Further study of dynamic collector principle.

Summary and Prospects.

TUHH

Summary

- BO-efficiency is important for modulated operation.
- Envelope simulation is a useful tool to evaluate the TWT's multi-tone behavior.
- Delay-line optimization improves efficiency and nonlinear distortions.
- Idea of dynamic collectors is promising.

Outlook

- Patterns and design-rules for delay-line.
- Further study of dynamic collector principle.

Thank you for your attention!

Acknowledgments

Funded by the German Space Agency (DLR) on behalf of
the Federal Ministry of Economics and Technology (BMWi).