

***ECE 145A / 218 C, notes set xx:  
Summary of Distortion  
and Large-Signal Limits***

***Mark Rodwell***

***University of California, Santa Barbara***

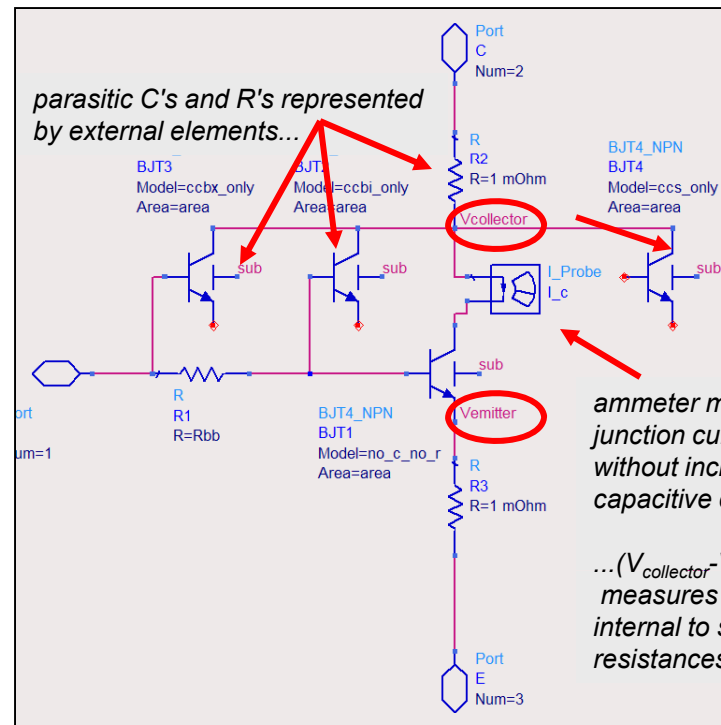
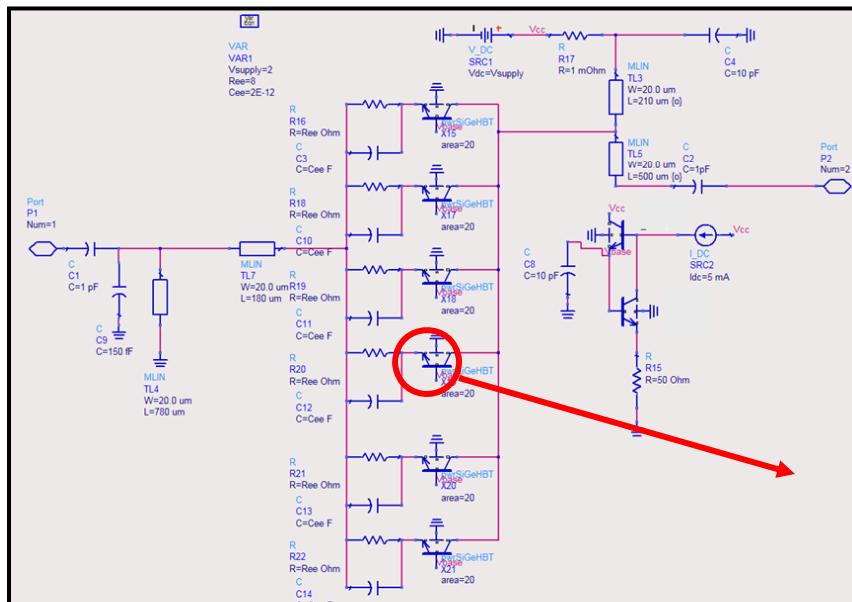
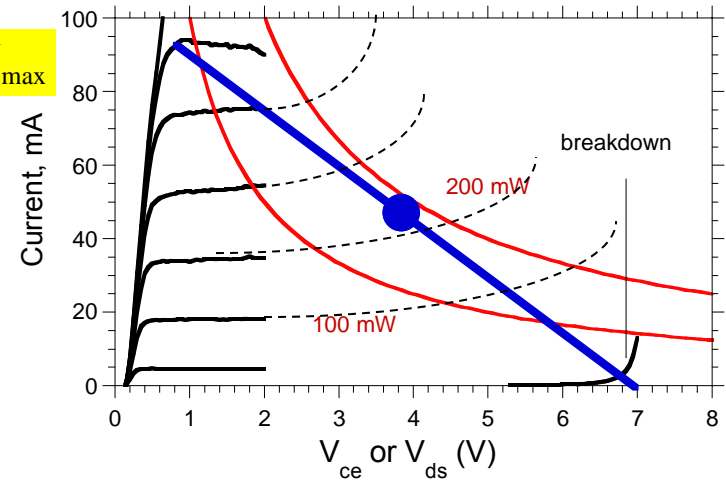
rodwell@ece.ucsb.edu 805-893-3244, 805-893-3262 fax

# Power Amplifier Design (Cripps method)

For maximum saturated output power, & maximum efficiency device intrinsic output must see optimum loadline set by:

$$P_{\max} = (1/8)(V_{\max} - V_{\min})I_{\max}$$

breakdown, maximum current, maximum power density.

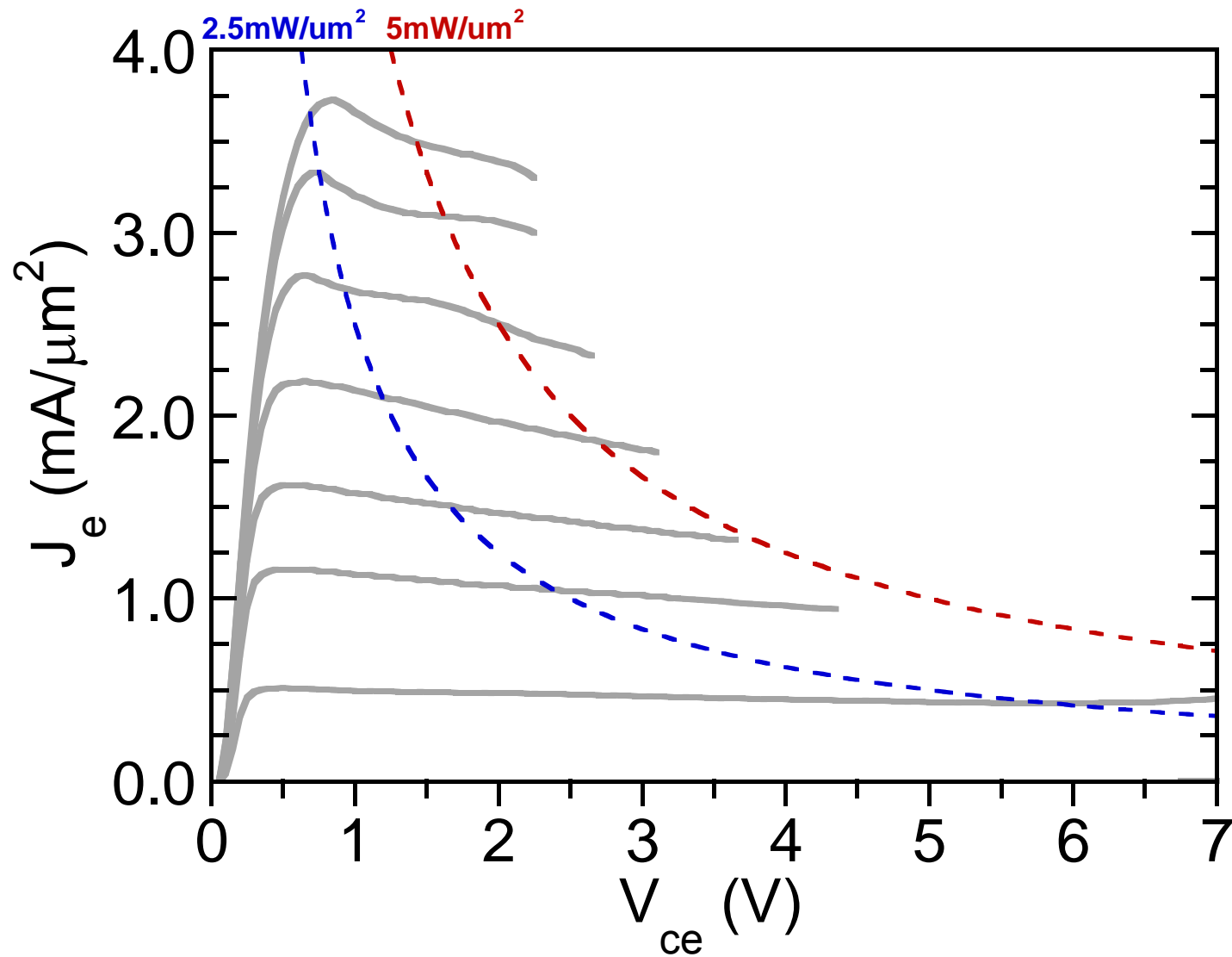


parasitic C's and R's represented by external elements...

ammeter monitors intrinsic junction current without including capacitive currents

...(V<sub>collector</sub>-V<sub>emitter</sub>) measures voltage internal to series parasitic resistances...

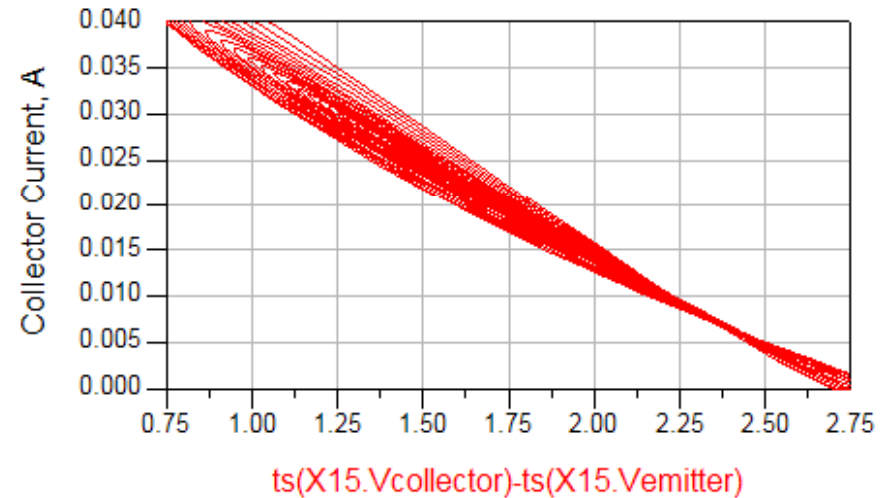
# Power HBT Common-Emitter Characteristics



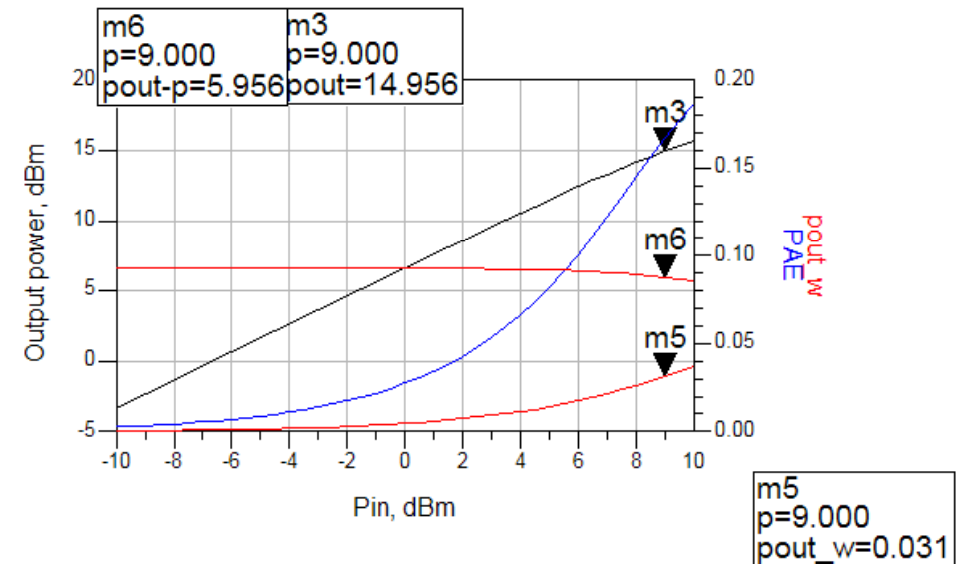
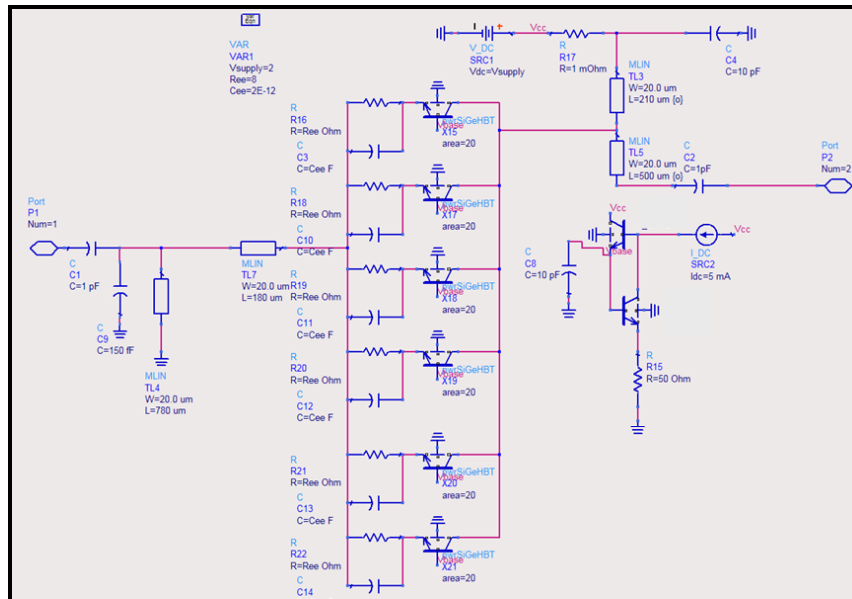
# Power Amplifier Design (Cripps Method)

Design steps are

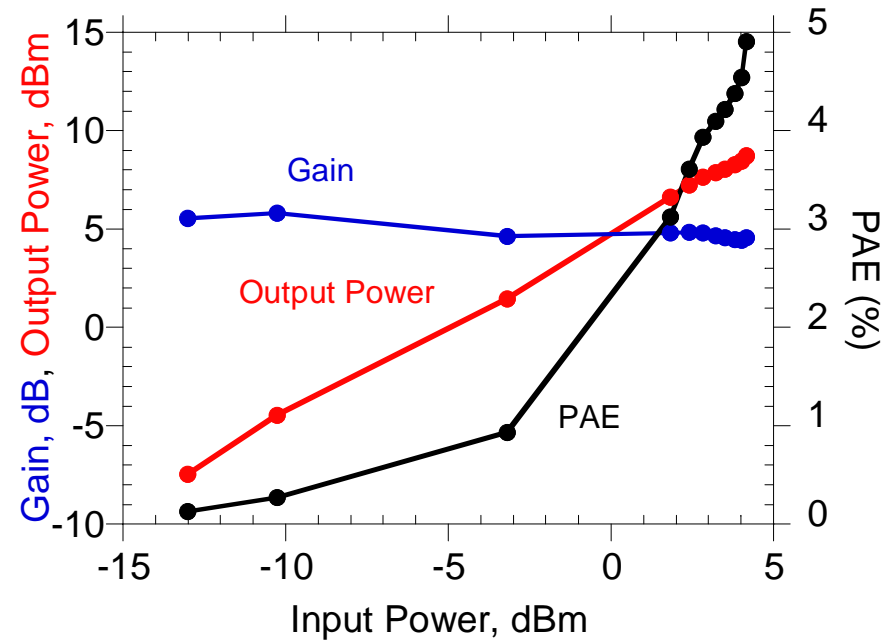
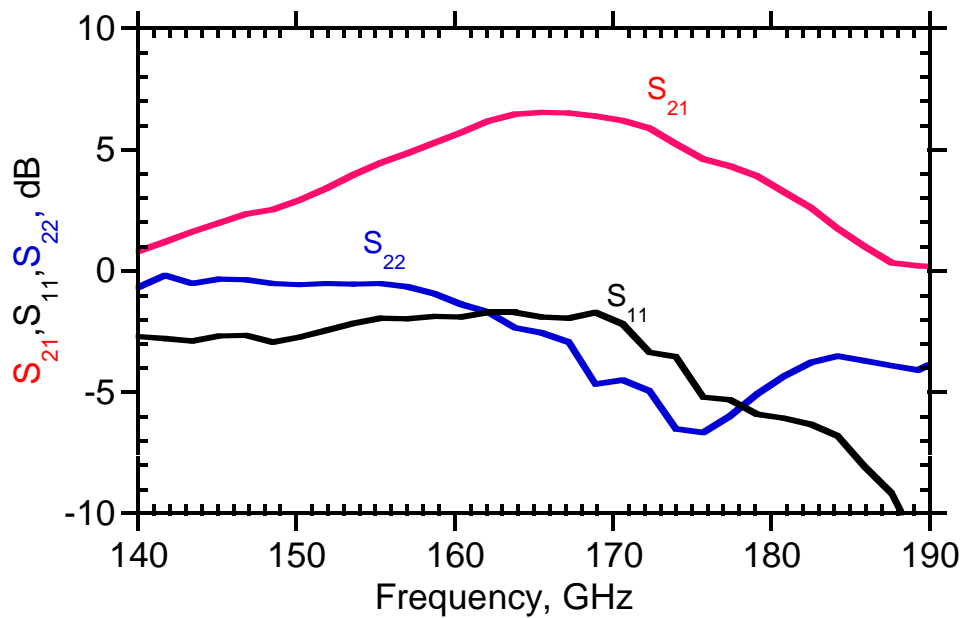
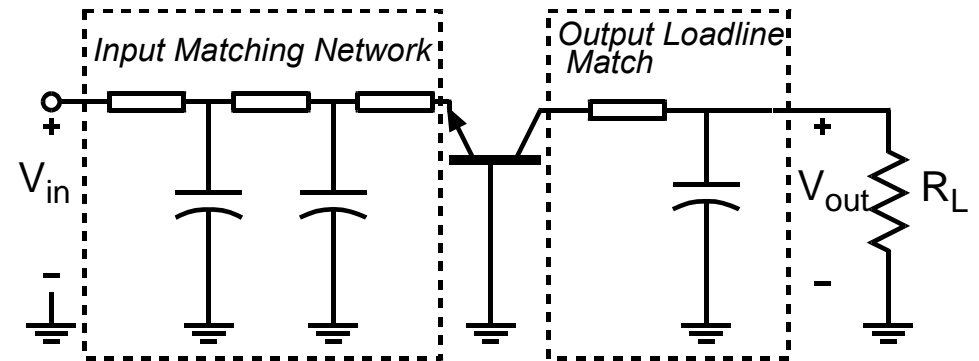
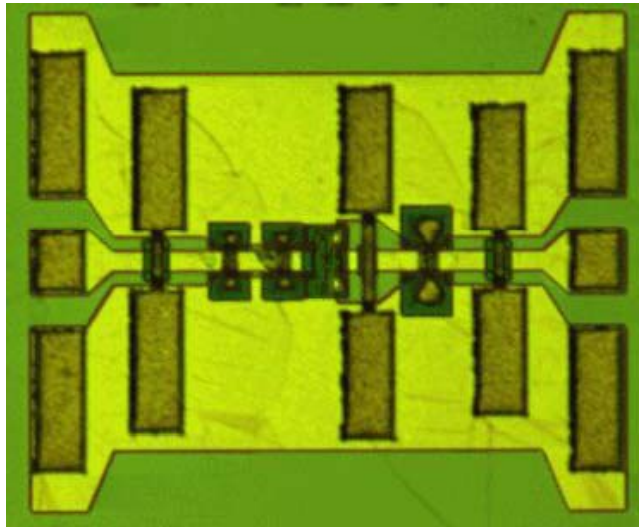
- 1) input stabilization (in-band)
- 2) output tuning for correct load-line
- 3) input tuning (match)
- 4) out-of-band stabilization



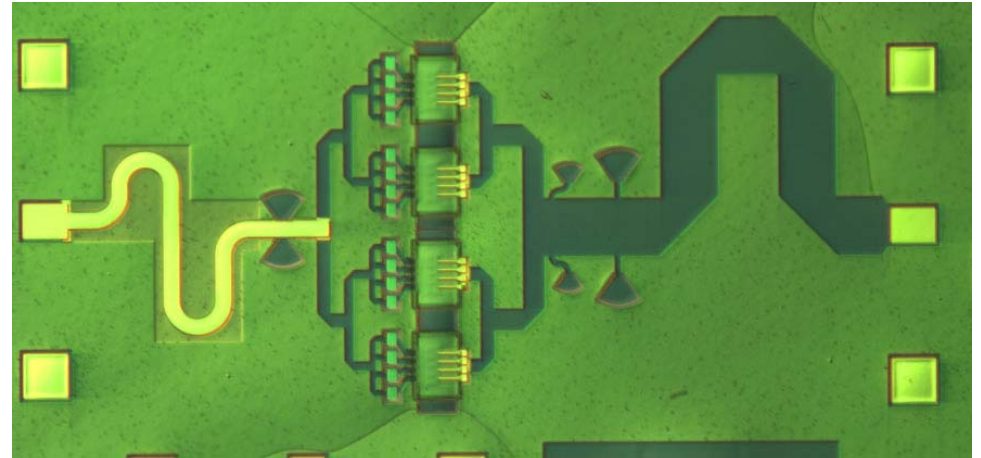
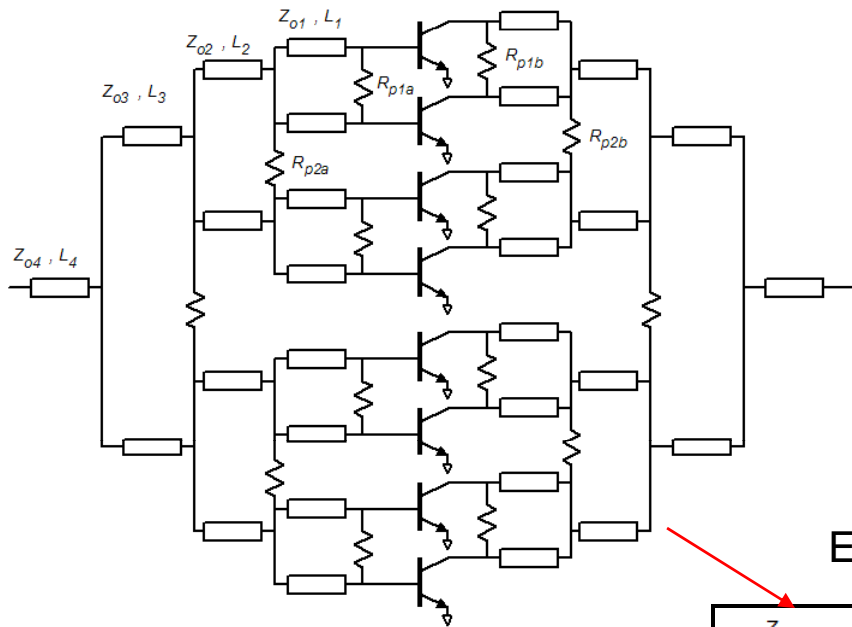
Example: 60 GHz, 30 mW PA, 130 nm BiCMOS



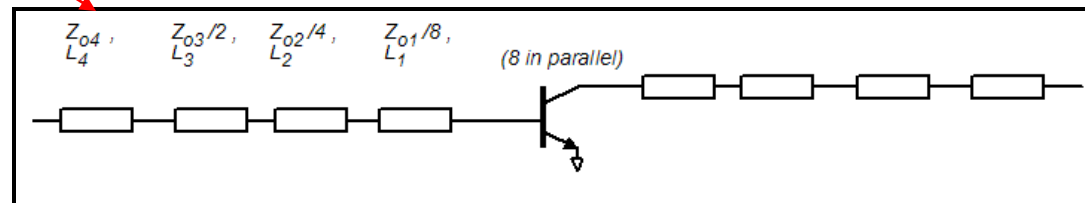
# Example: 175 GHz Medium-Power (7 mW) HBT Amplifier



# Design: Multi-Finger Power Amplifiers: Even-mode method



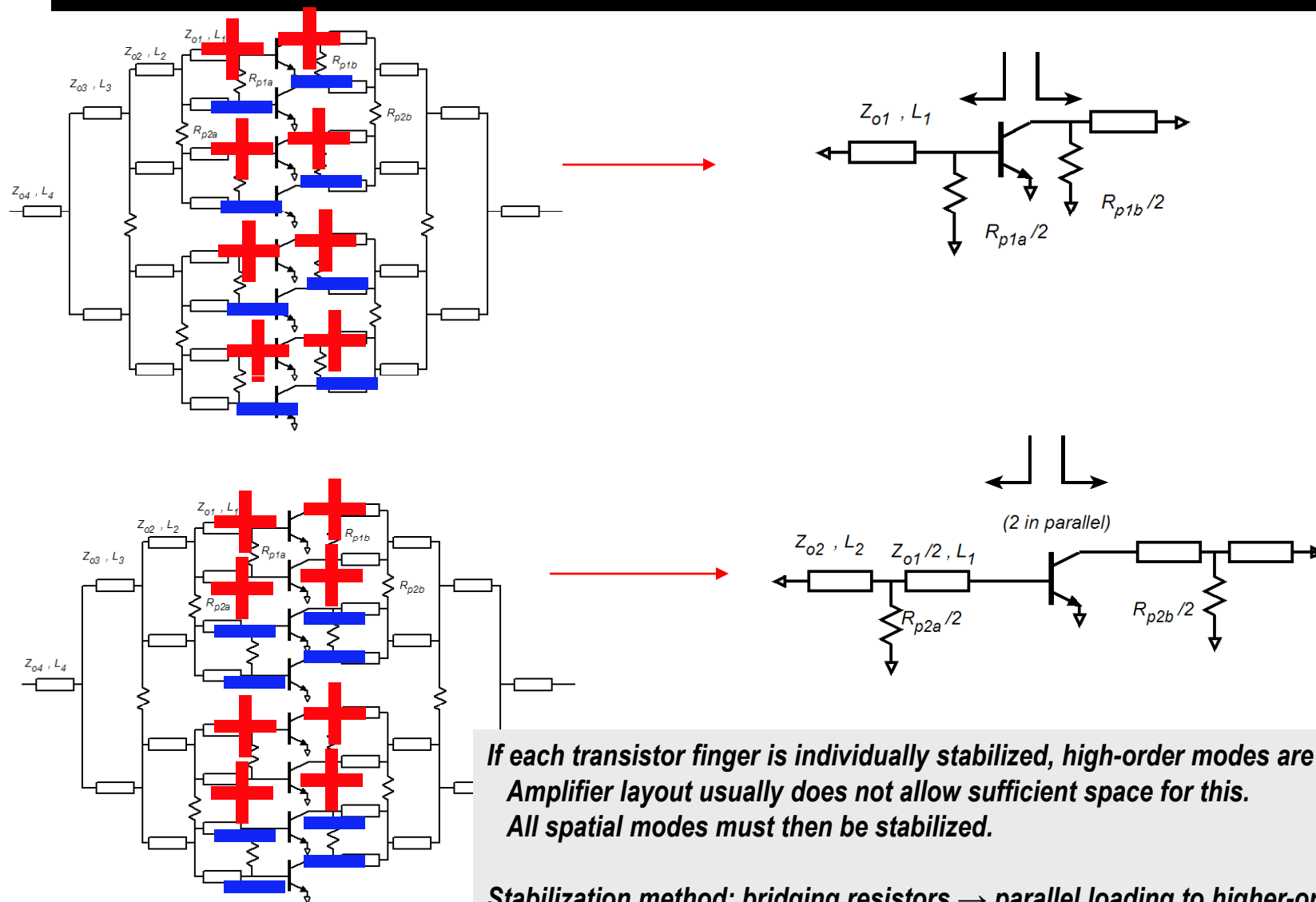
Even-mode equivalent circuit



- Most multi-finger amplifiers do not use Wilkinson combiners: lines are too long
- Even-mode equivalent circuit maps combined design into single-device design
- Final design tuning (E&M simulation) with full circuit model

***This method explicitly models all feed parasitics in a large multi-finger transistor  
MUCH more reliable than using single lumped model for multi-finger device***

# Design: Multi-Finger Amplifiers: spatial mode instabilities



**If each transistor finger is individually stabilized, high-order modes are stable. Amplifier layout usually does not allow sufficient space for this. All spatial modes must then be stabilized.**

**Stabilization method: bridging resistors → parallel loading to higher-order modes**  
**Select so that  $(Z_S, Z_L)$  presented to device lie in the stable regions**

**etc...**

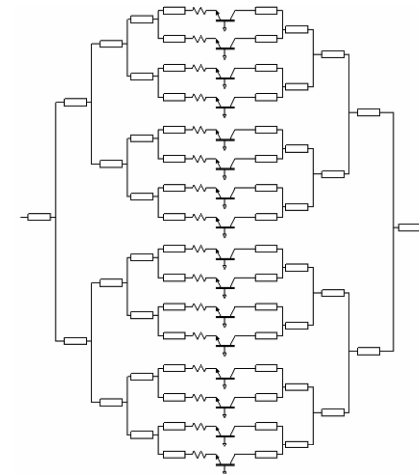
# Example: 330 GHz 16-Finger Power Amplifier Design

designs in progress: Michael Jones  
 device: 5 V, 650 GHz  $f_{max}$  InP DHBT  
 wiring: thin film microstrip with 2  $\mu$ m BCB

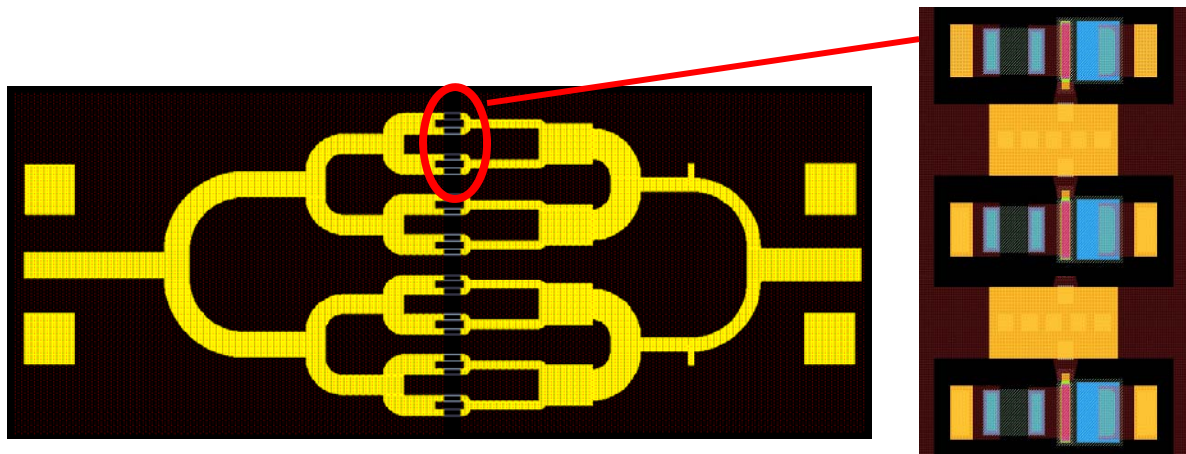
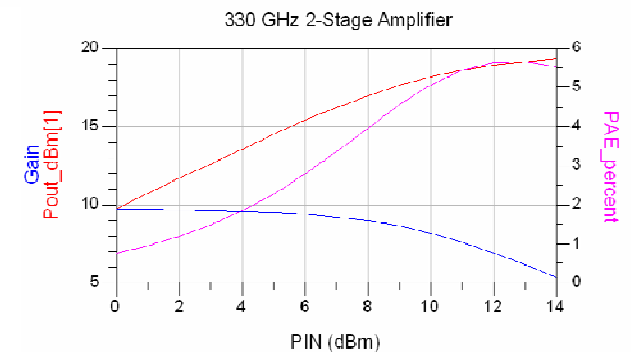
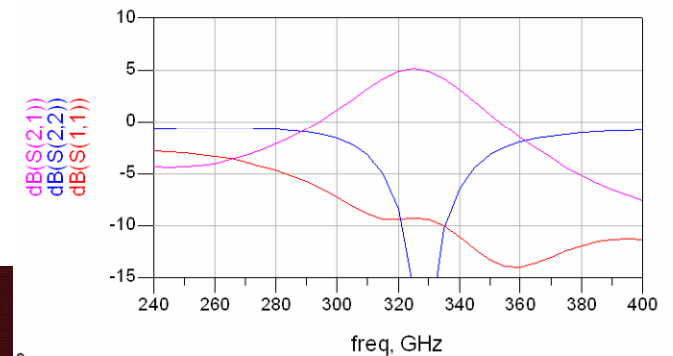
## Challenges:

- line losses are very high
- lines  $> 60 \Omega$  are not feasible  $\rightarrow$  increases Q of output tuning
- lines of required impedance are narrow  $\rightarrow$  limits on DC current

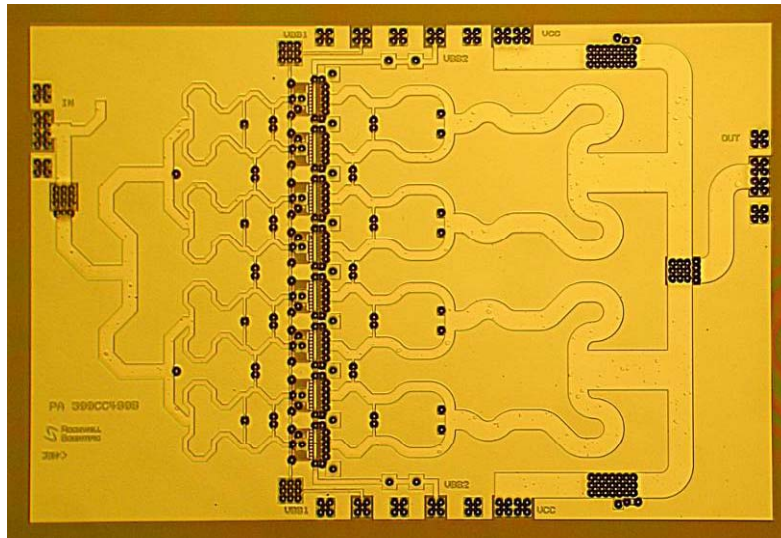
small unmodeled parasitics will de-tune design  
 ....must maintain microstrip environment to device vias  
 with negligible lengths of unmodeled random interconnects



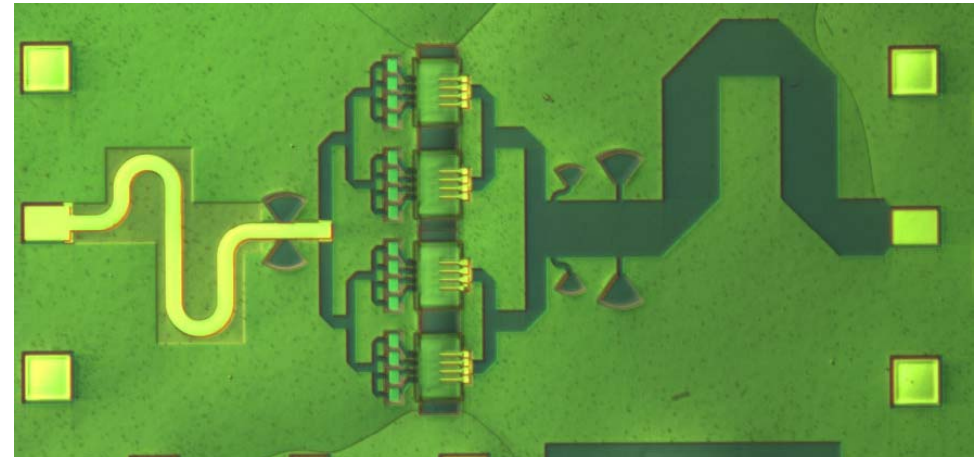
330 GHz 16-Finger Amplifier



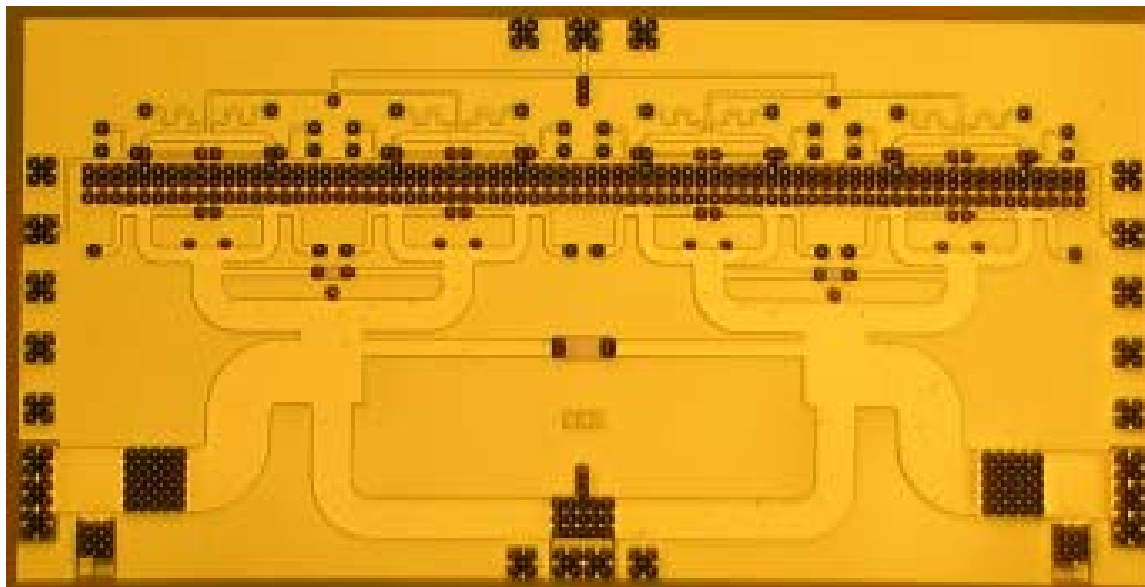
# Design: Multi-Finger Amplifiers: Layout Examples



*mm-wave InP HBT power amplifier - Rockwell*



*W-band InP HBT power amplifier - UCSB*



*mm-wave InP HBT power amplifier - Rockwell*