Passive components for RF and microwave circuits: lumped components

Layout and package

Microwave Electronics

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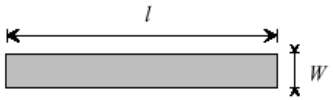
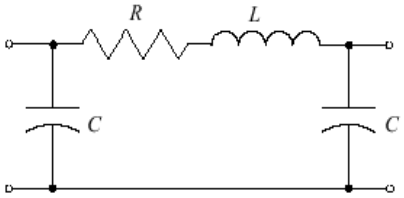
Lumped elements

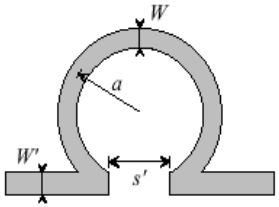
- Inductors and capacitors can be obtained from short lines in short or open-circuit, respectively
- Spiral inductors exhibit larger inductances but also larger parasitic capacitances→ resonant frequency is typically below 20 GHz
- Larger capacitors can be obtained from the interdigitated and MIM approaches, very large capacitors must be inserted as external elements (chip capacitors)
- Resistors can be obtained from resistive strips or doped regions, they can also be inserted externally (chip resistors)

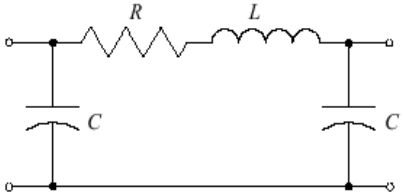
Inductors



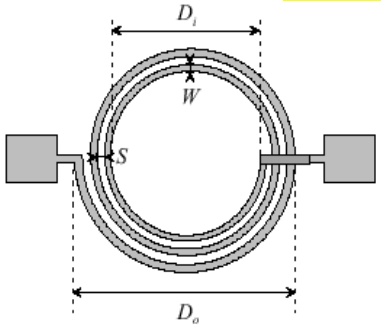


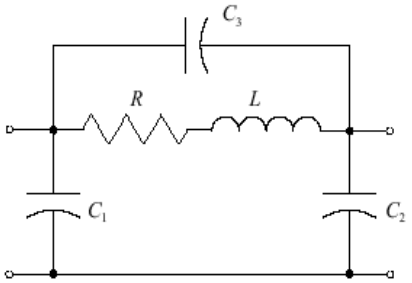
Strip



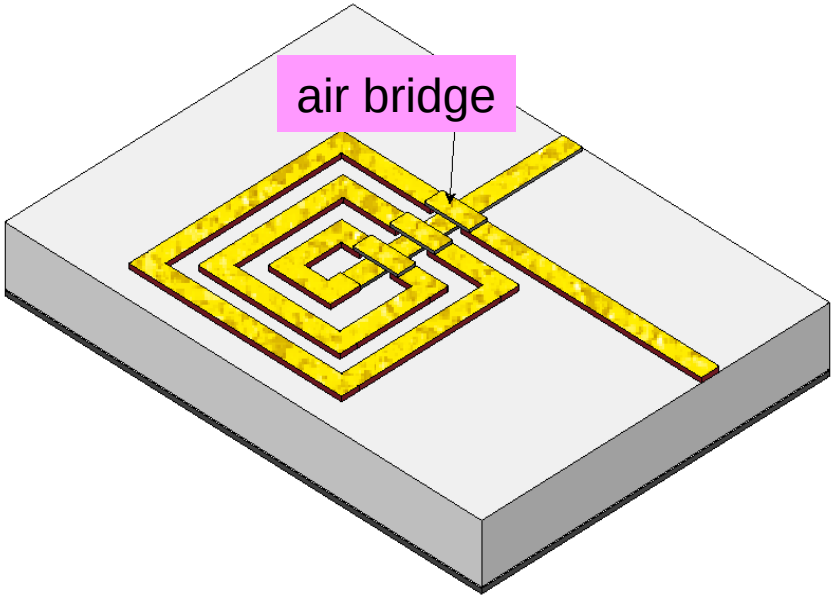


Loop



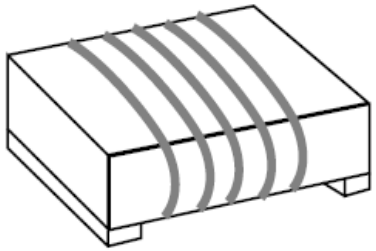


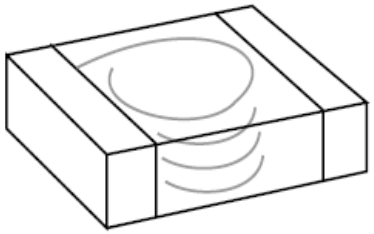
Spiral



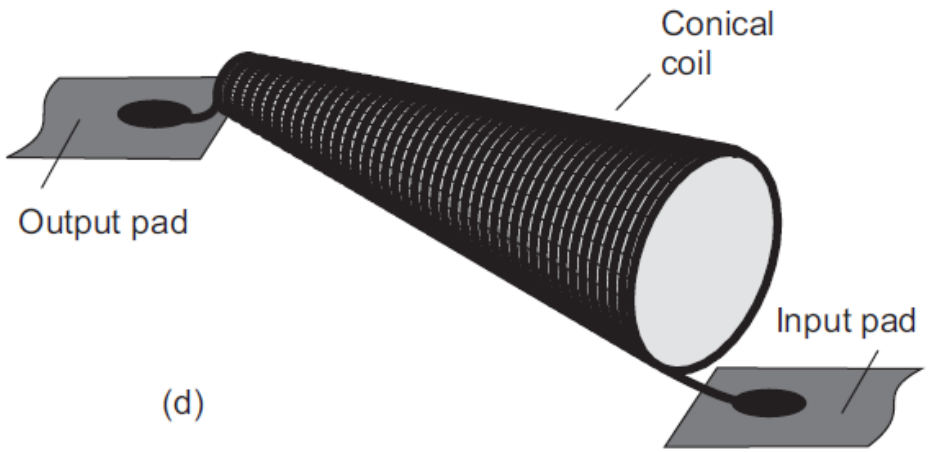
Spiral with air bridge

RF Chip and Conical inductors



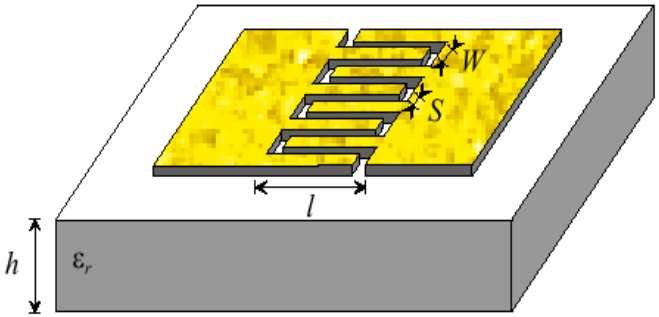


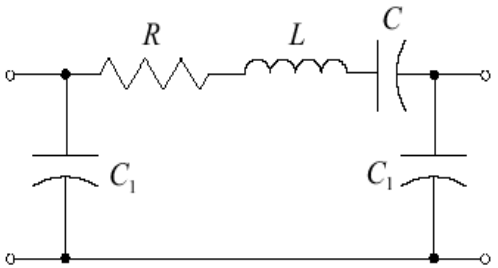
Type	Size	Inductance Range	Q Range	Current Range	Resonance Range
Wound					
	603	1.8–120 nH	10–90	0.3–0.7 A	1.3–6 GHz
	805	3.3–220 nH	10–90	0.3–0.8 A	0.8–6 GHz
	1008	3.3–10,000 nH	10–100	0.24–1 A	0.06–6 GHz
	1812	1.2–1000 μH	10–60	0.05–0.48 A	1.5–230 MHz
Multilayer					
	402	1–27 nH	10–200	0.3 A	1.6–6 GHz
	603	1.2–100 nH	5–45	0.3 A	0.83–6 GHz
	805	1.5–470 nH	10–70	0.1–0.3 A	0.3–6 GHz



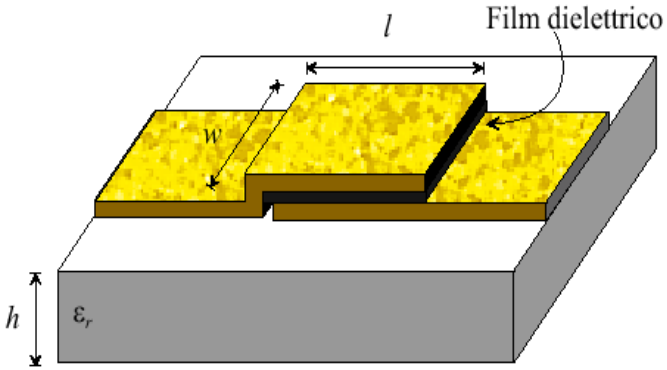
(d)

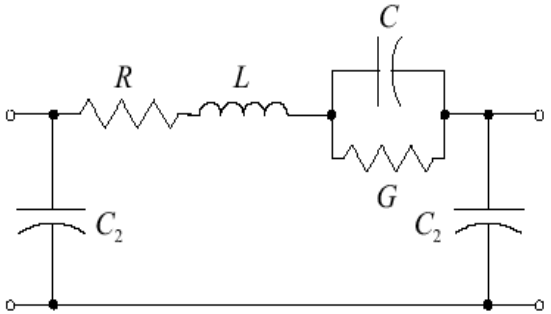
Capacitors





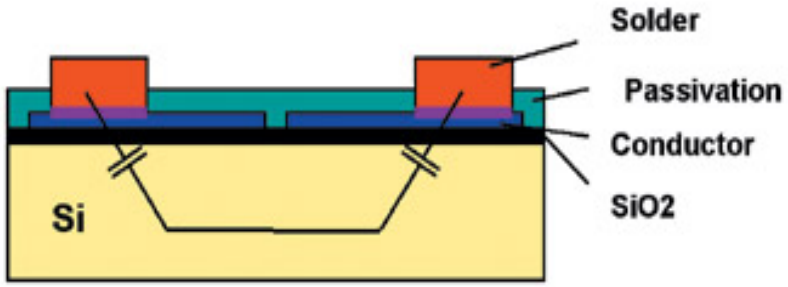
Interdigitated





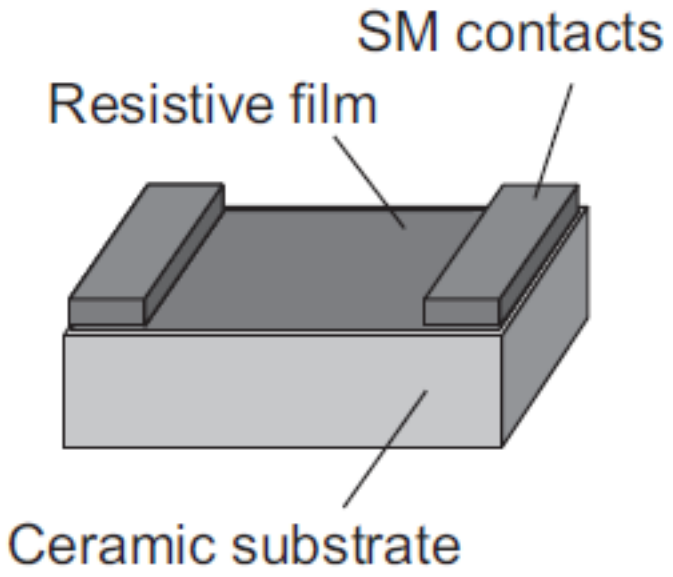
MIM

Chip capacitors - surface-mount

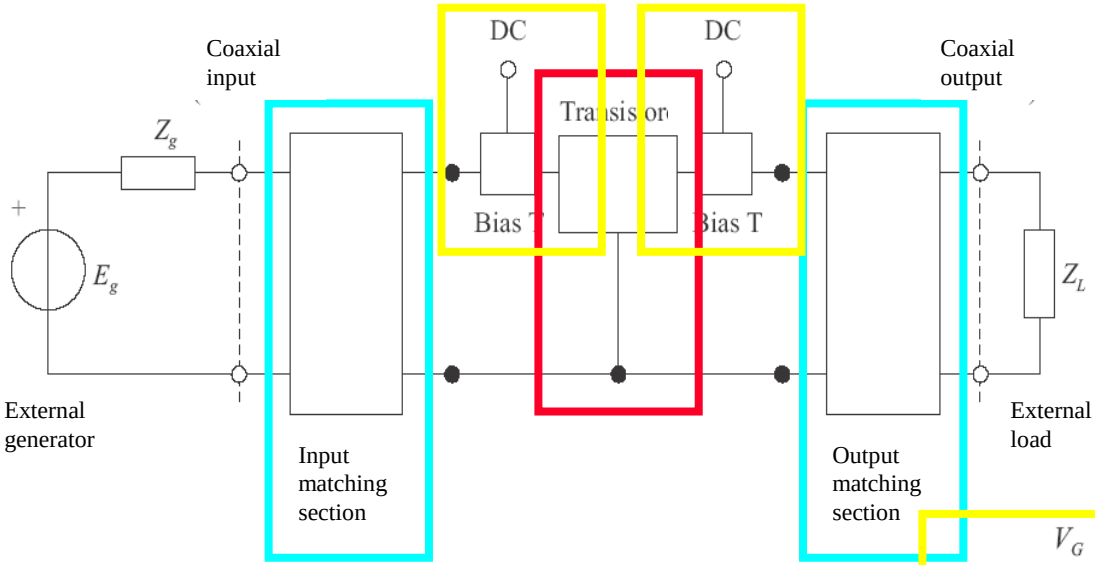


Type	ε_R	Temp. Co. (ppm/degC)	Tol (%)	Range (pF in 805)	Voltage Coeff. (%)
NPO	37	0+/–30	1–20	0.5 p–2200 p	0
4	205	–1500+/–250	1–20	1 p–2200 p	0
7	370	–3300+/–1000	1–20	1 p–2200 p	0
Y	650	–4700+/–1000	1–20	1 p–2200 p	0
X7R	2200	+/–15%	5–20	100 p–1 μ	+0/–25
Z5U	9000	+22/–56%	+80/–20	0.01 μ–0.12 μ	+0/–80

Chip resistor

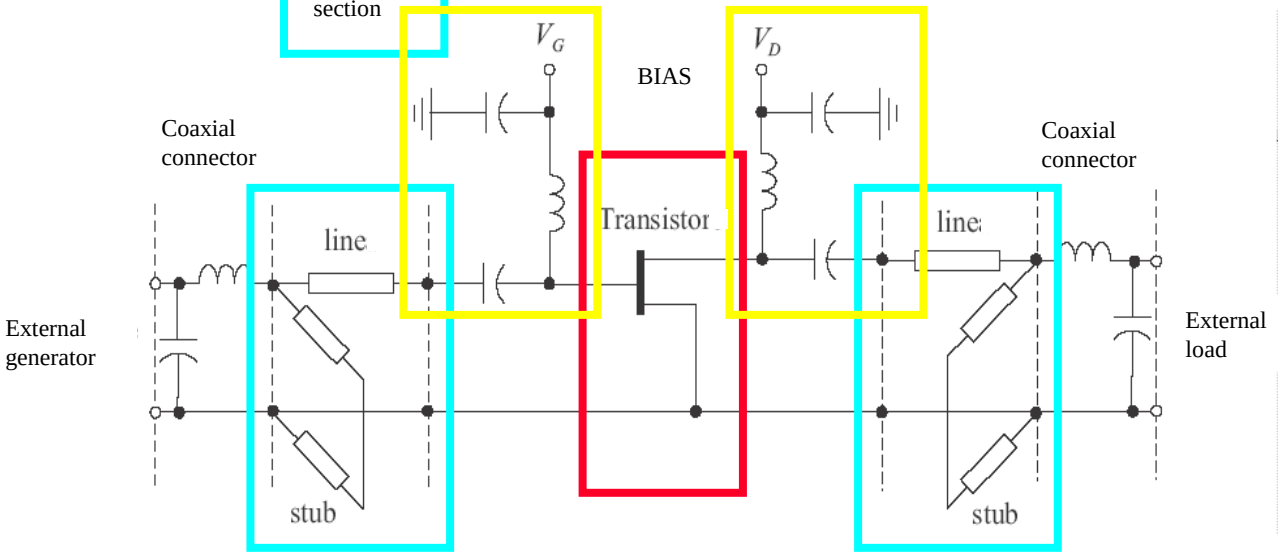


Block scheme to netlist: a single stage RF amplifier

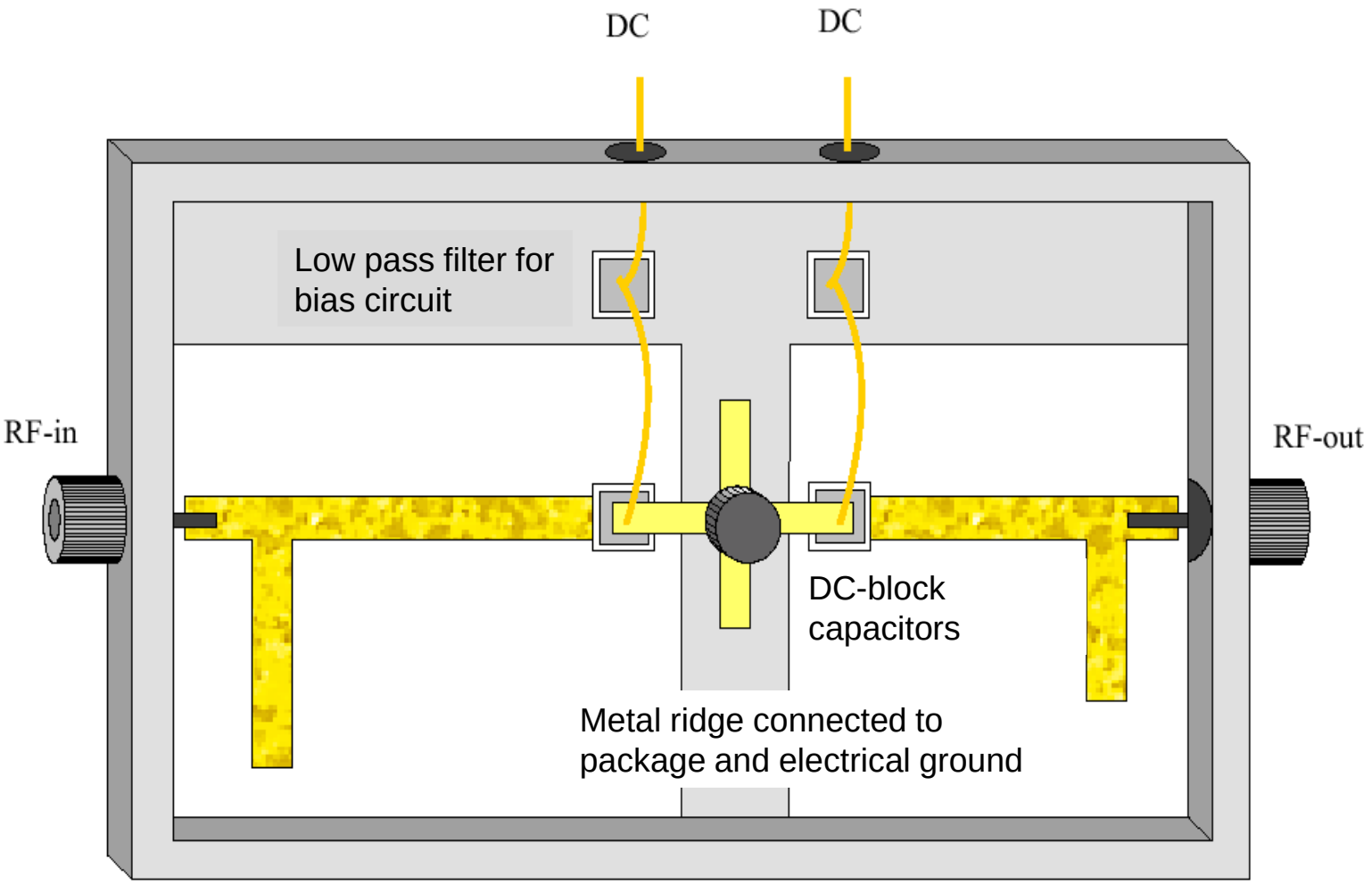


Block scheme

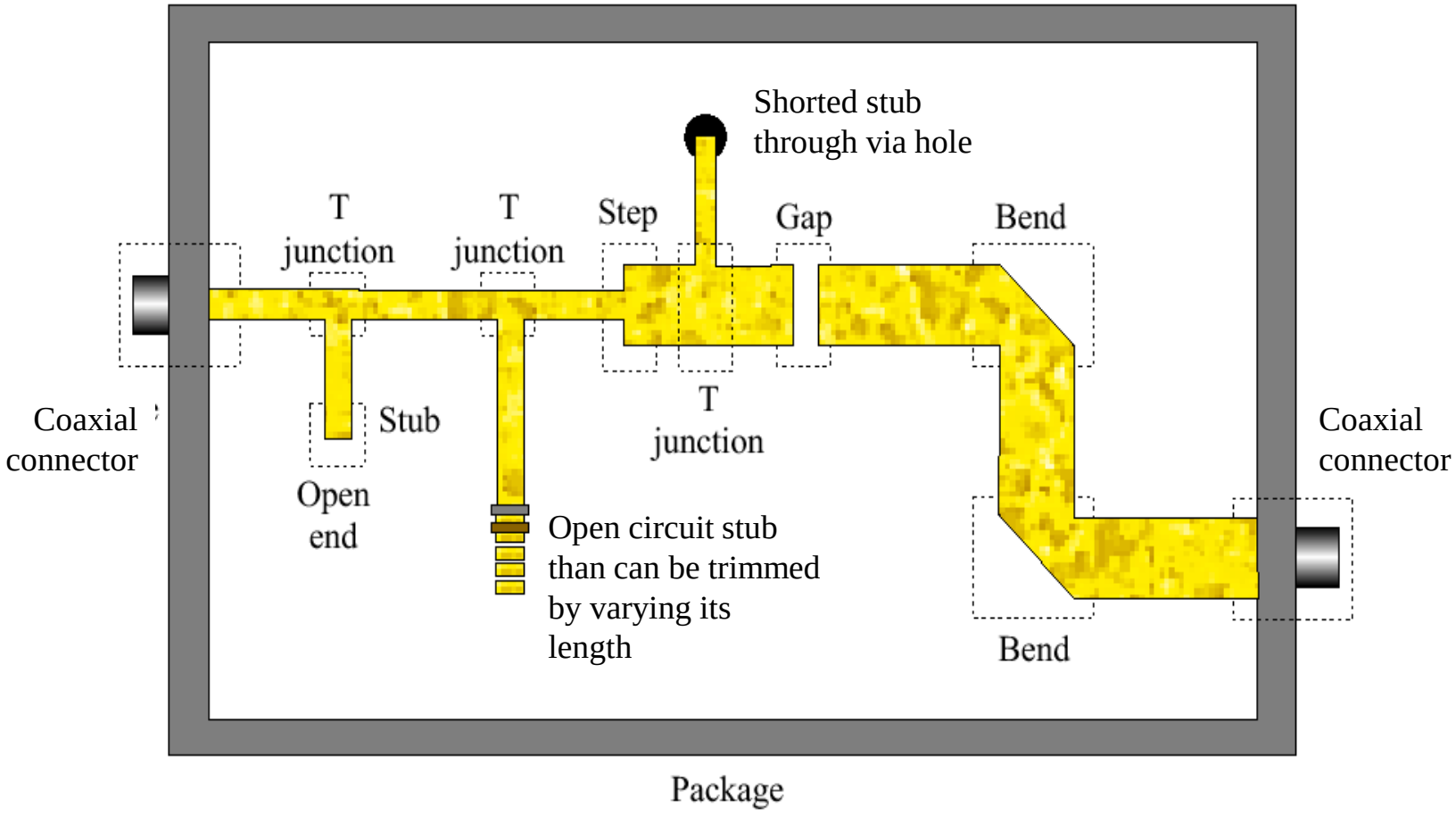
Circuit → netlist



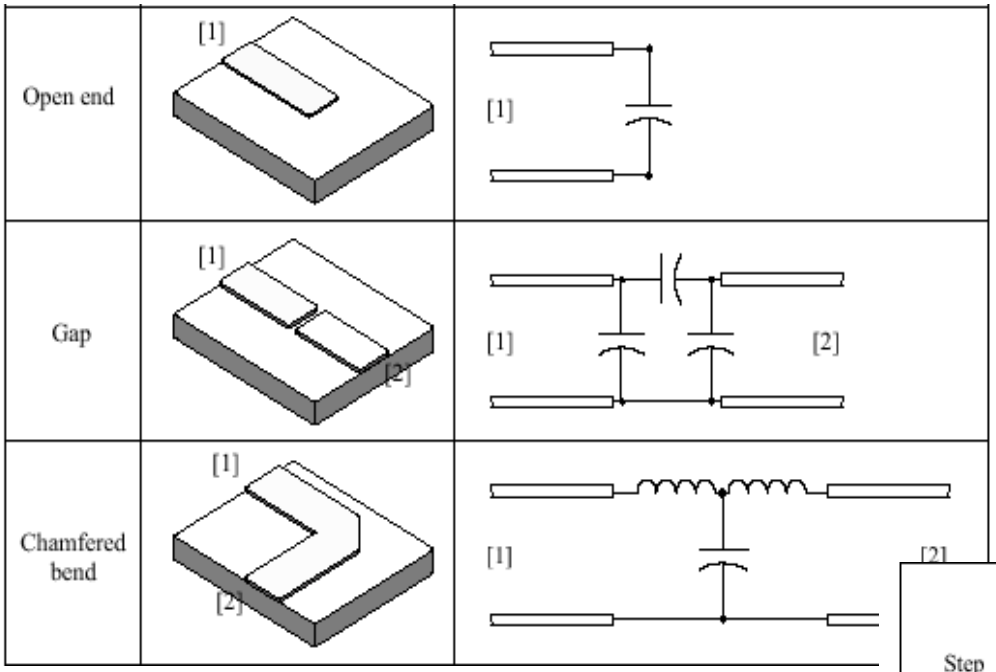
Netlist to microstrip layout



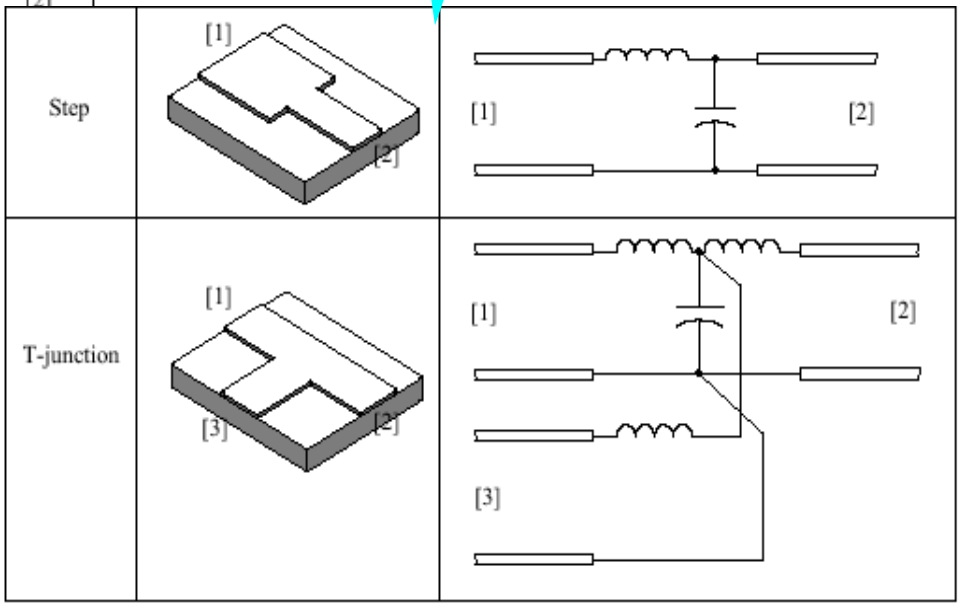
Microstrip discontinuities



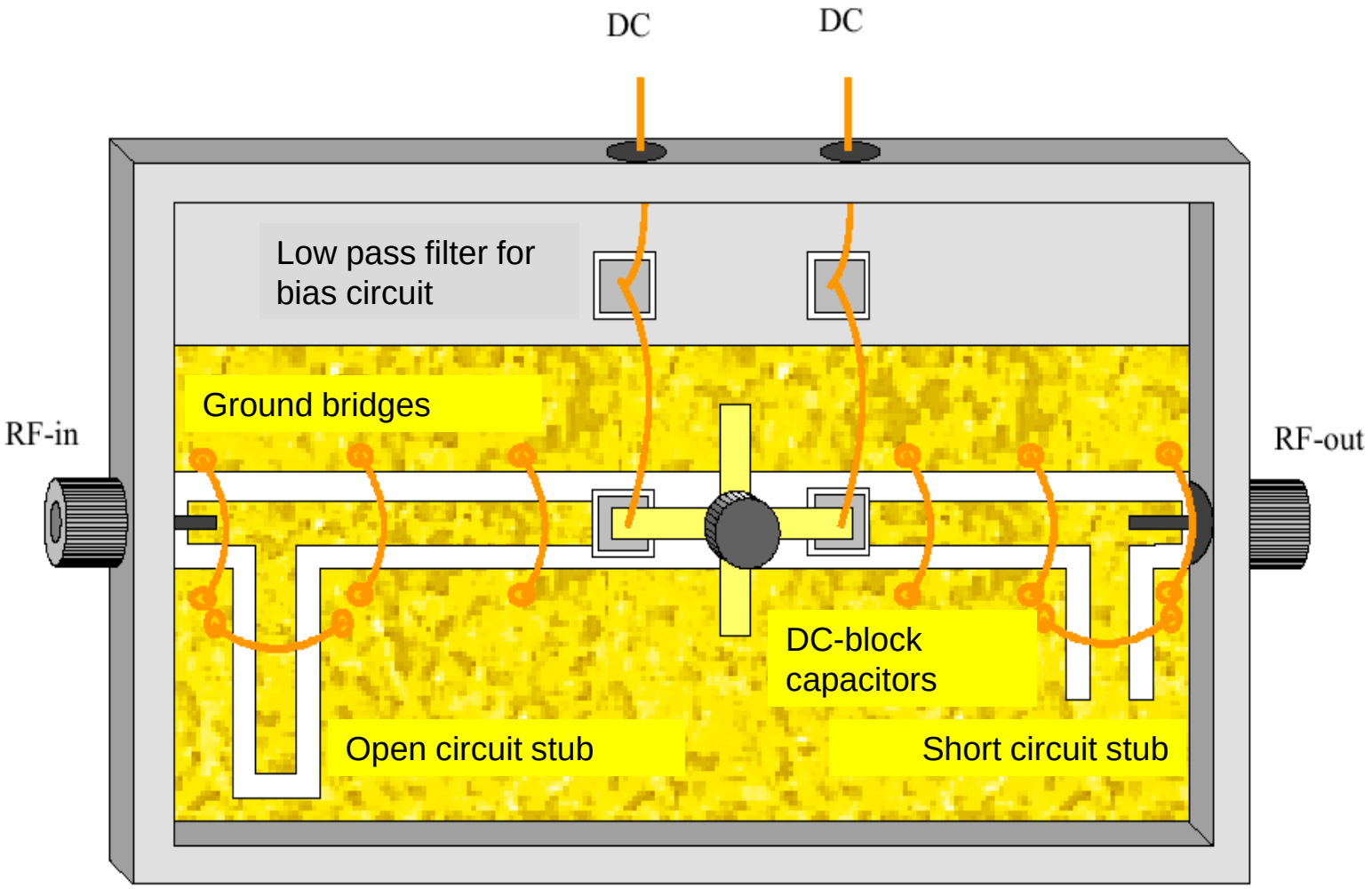
Discontinuity equivalent circuits



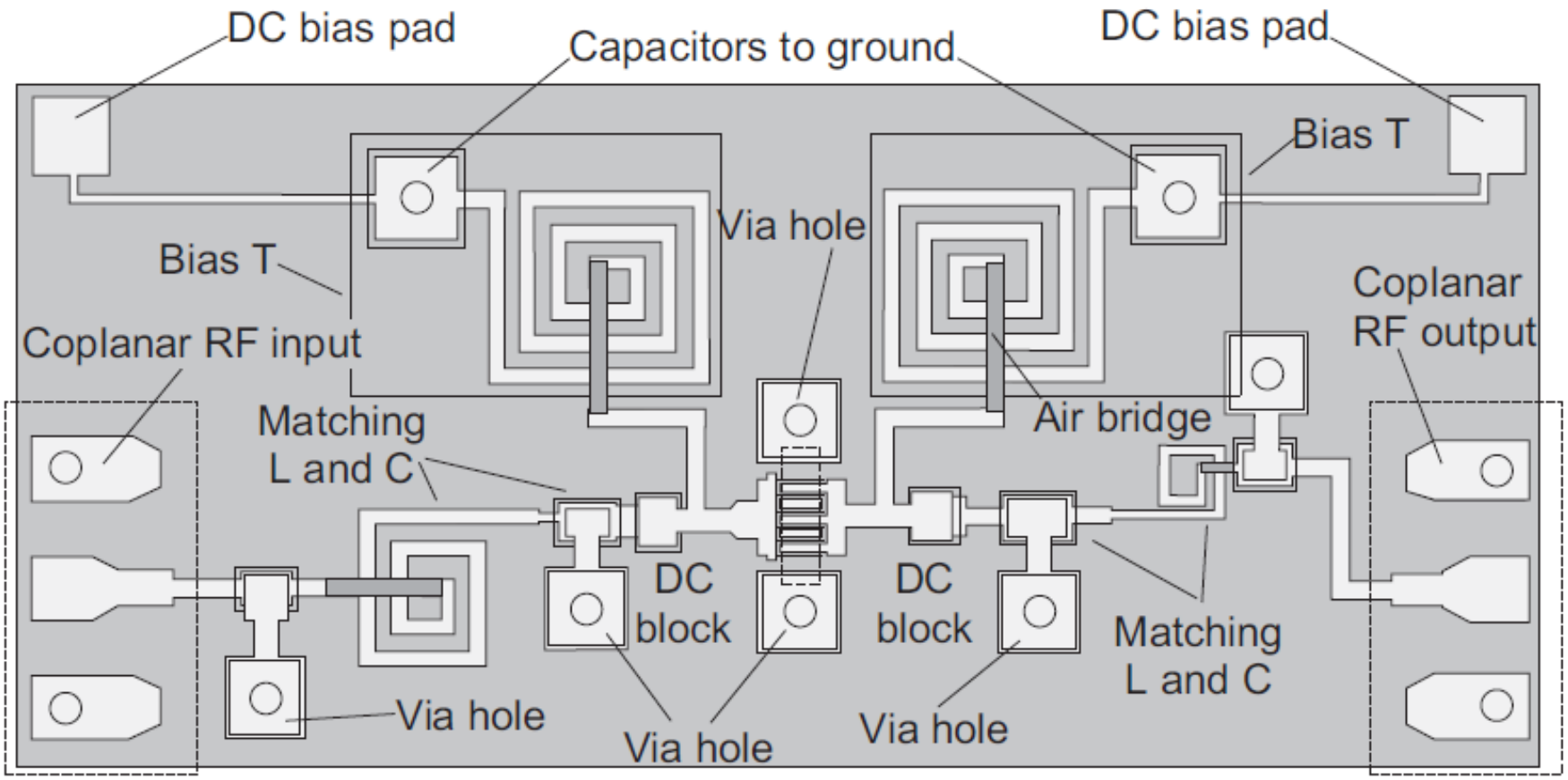
Off-the-shelf models in any CAD tool!



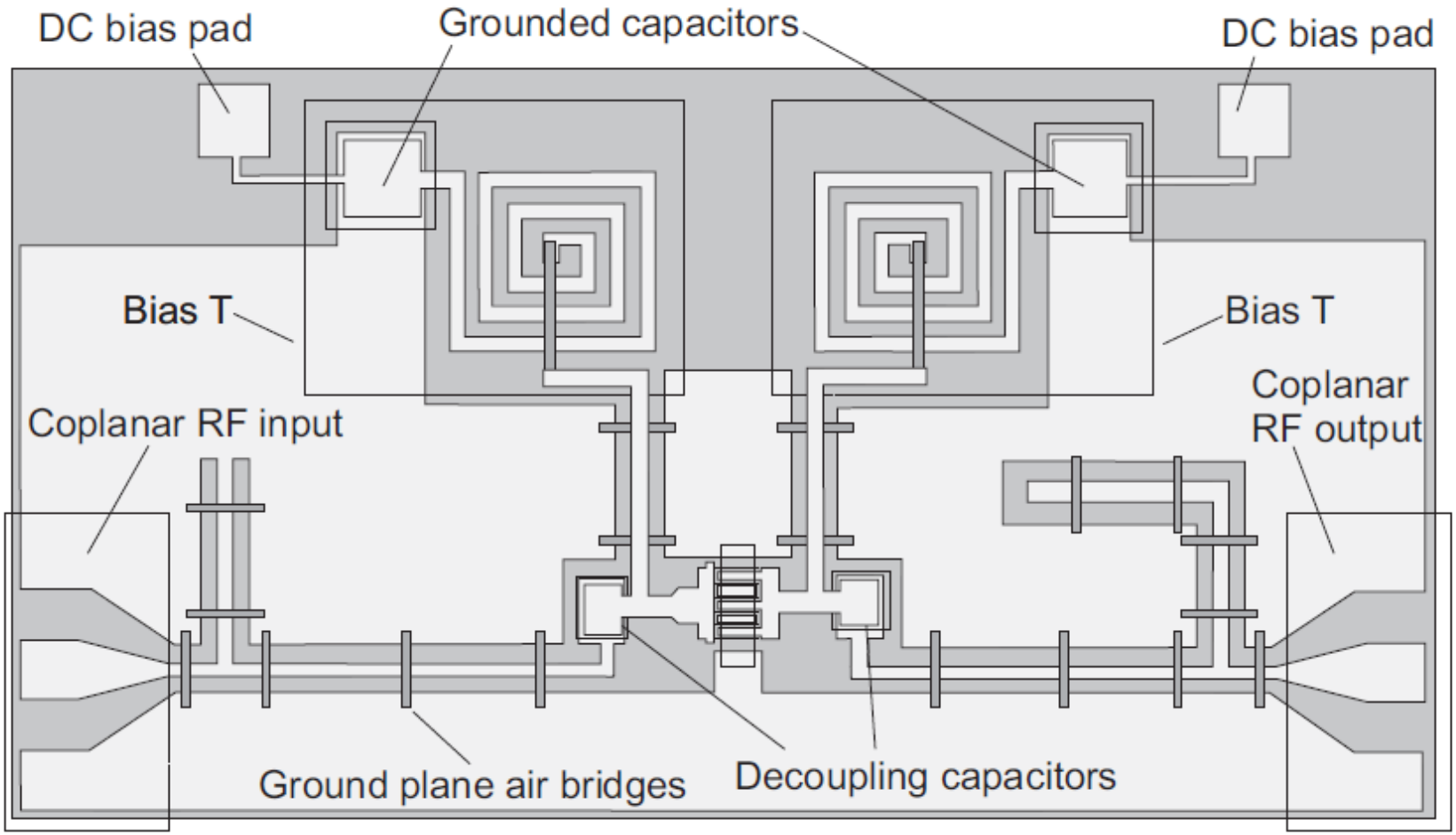
Coplanar layout (single stage amplifier)



Microstrip Integrated Circuit Layout

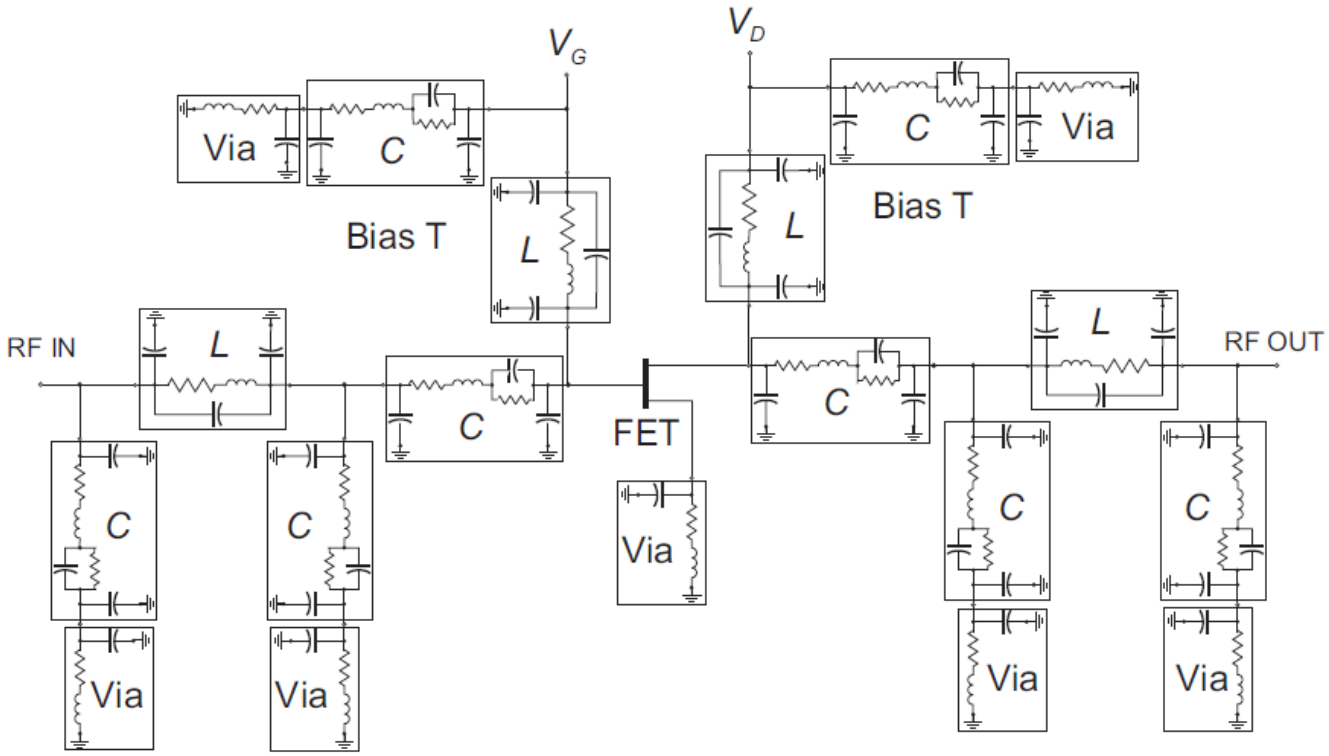


Coplanar integrated circuit layout



1-stage amplifier with real elements

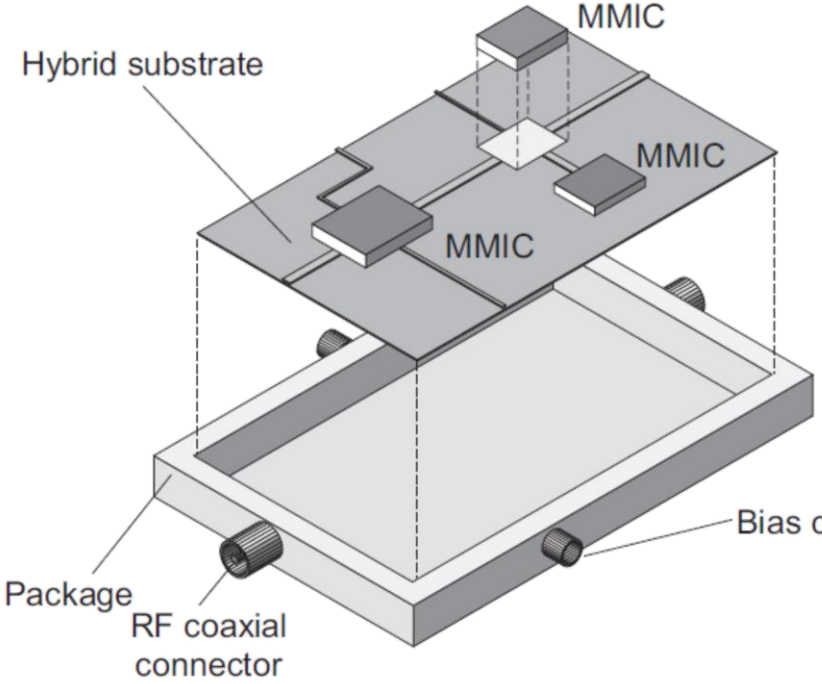
- Purpose: to outline the design cycle: ideal netlist → optimization → layout → extraction of an augmented netlist → verification → redesign

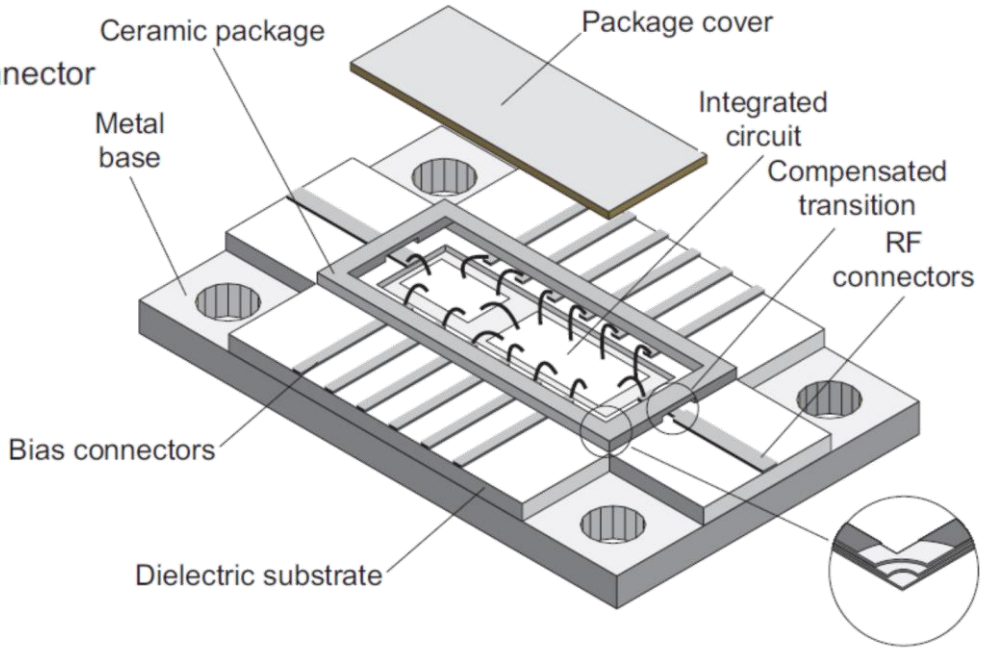


Package

- Should:
  - Protect the circuit mechanically, offer EM shielding, protect the circuit from chemicals
  - Allow for heat dissipation
  - Be as transparent as possible from the electrical standpoint
  - Should not introduce internal resonances and spurious mode couplings
- Approaches:
  - Metallic package (high Q)
  - Dielectric packages (low Q → MIM stratified)
  - Hermetic – in air housing
- Transitions: to coax (K, V etc.), to microstrip (flatpack)

Metllic and ceramic package examples





Examples of coax transitions

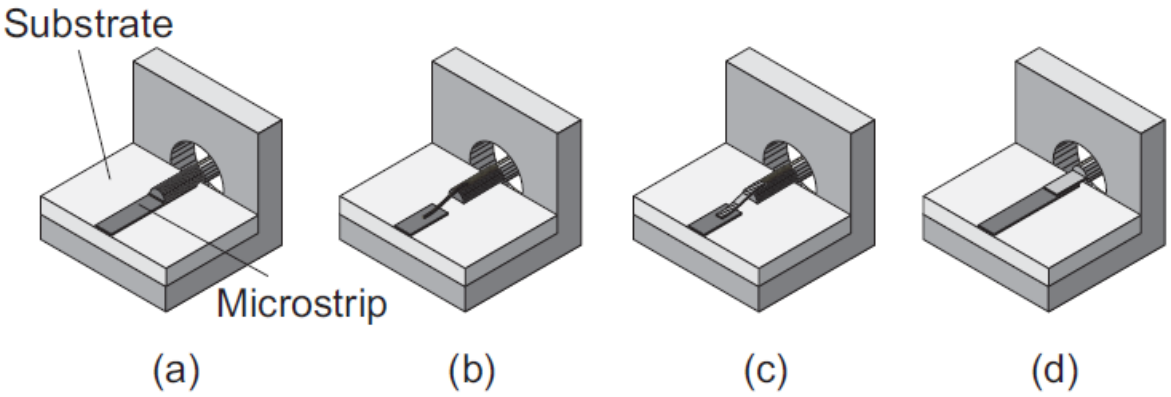


Figure 2.41 Coaxial-microstrip transitions.

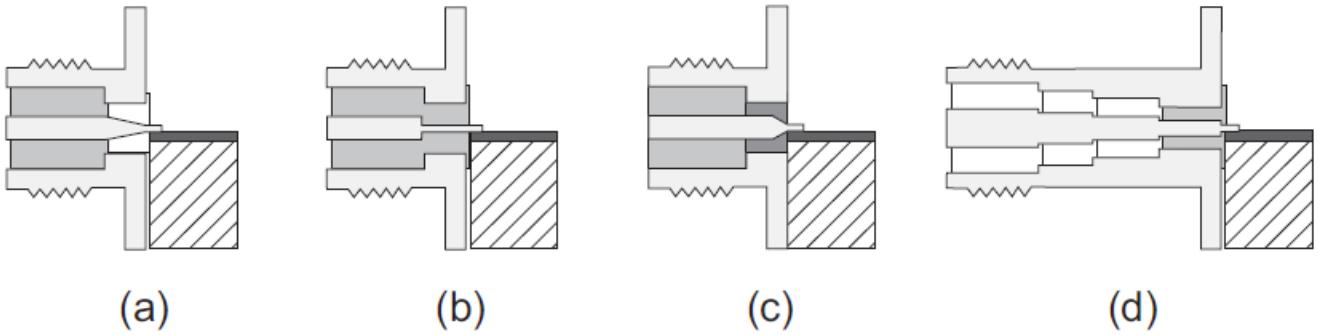


Figure 2.42 Examples of transitions between 3/7 coax or SMA connector and microstrip on allumina substrate: (a) Air transition; (b) Step transition; (c) Hermetic step transition; (d) Multiple step transition.