

Modeling Physical Interconnects

(Part 1)

Dr. José Ernesto Rayas Sánchez

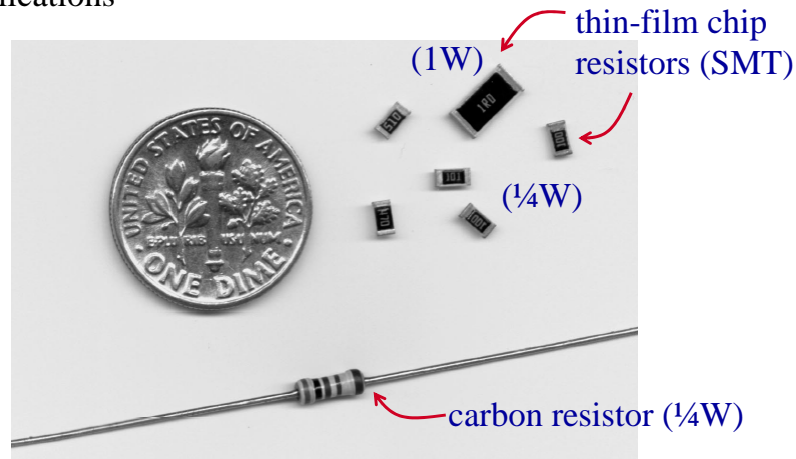
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Outline

- Lumped resistors
- Lumped capacitors
- Lumped inductors

Lumped Resistors

Thin-film chip resistors are used for RF and microwave applications

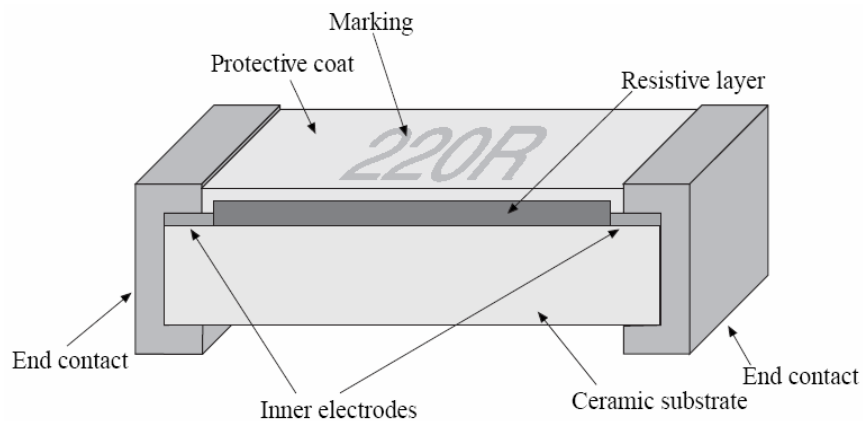


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(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000)₃

Lumped Resistors (cont)

Typical thin-film chip resistor

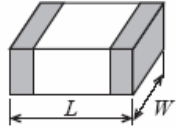


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(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000)₄

Lumped Resistors (cont)

Standard sizes for thin-film chip resistors

Geometry	Size Code	Length L, mils	Width W, mils
	0402	40	20
	0603	60	30
	0805	80	50
	1206	120	60
	1218	120	180

Resistance value range: $10^{-1} - 10^6 \Omega$

Typical tolerances: $\pm 5\%$ to $\pm 0.01\%$

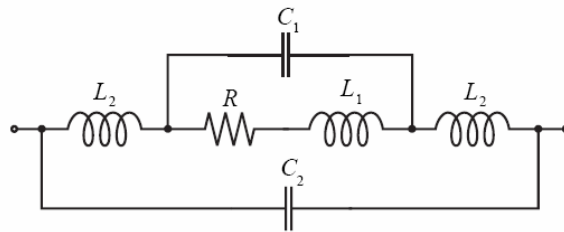
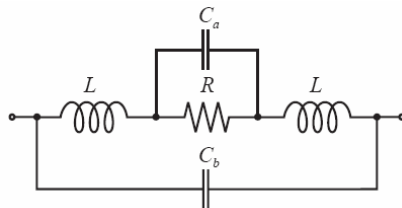
Power ranges: 0.25W to 1000W

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(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000)₅

Lumped Resistors (cont)

Approximate equivalent circuits:

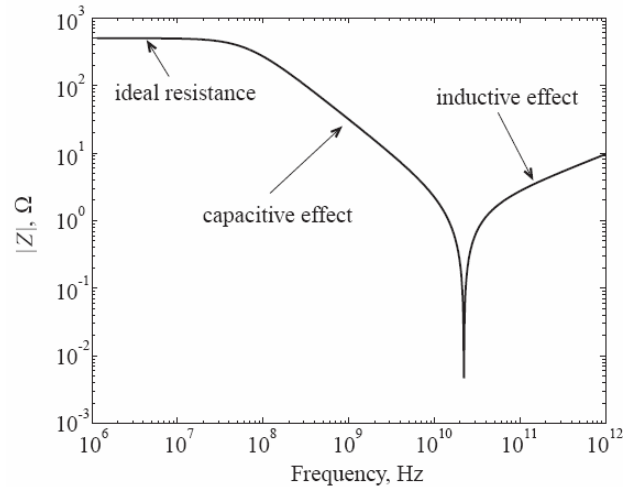


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(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000)₆

Lumped Resistors (cont)

Typical behavior (500- Ω thin-film resistor)

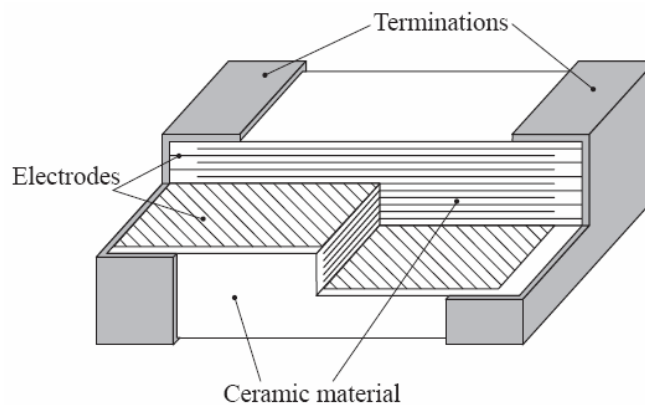


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Lumped Capacitors

SMT ceramic capacitors are the most common kind of lumped capacitor for RF and microwave applications



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(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000)₈

Lumped Capacitors (cont)

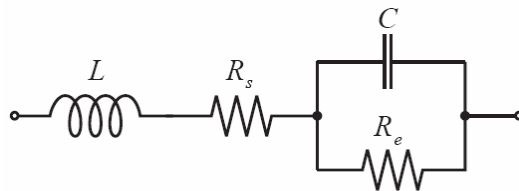
- Capacitance value range: 0.1pF – 1μF
- Typical tolerances: ±2% to ±50%
- Operating voltage range: 16V – 63V
- Standard sizes: from 15mil×15mil to 400mil×425mil

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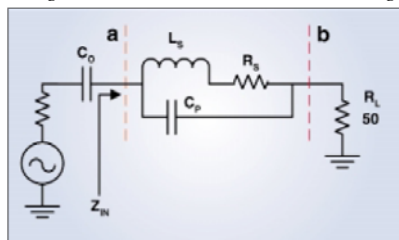
(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000),₉

Lumped Capacitors (cont)

Approximate equivalent circuit models



(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000)



▲ Figure 5. Nominal capacitor C_0 with parasitic elements.

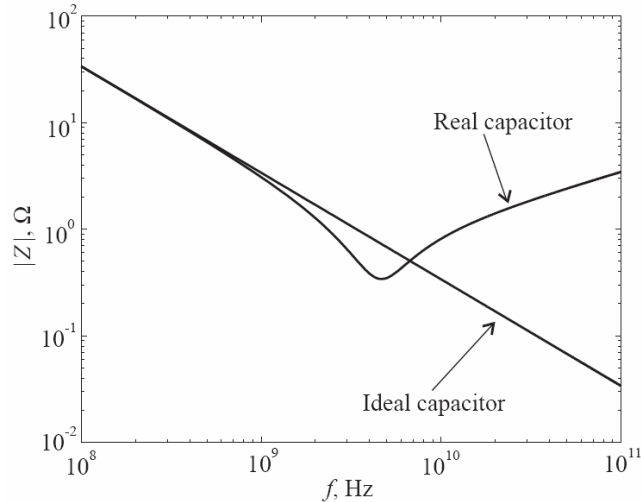
(R. Fiore, *Microwave and Wireless Applications*, May 2001)

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Lumped Capacitors (cont)

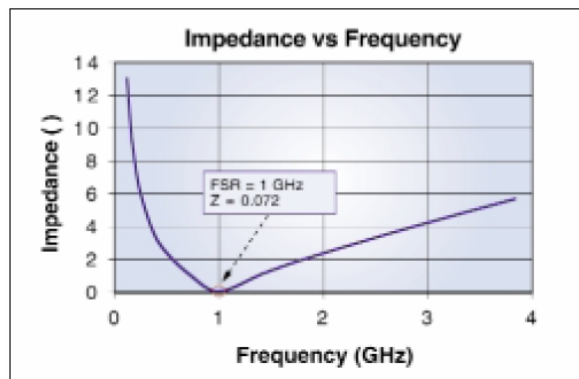
Typical behavior (47pF SMT ceramic capacitor)



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(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000)₁₁

Lumped Capacitors (cont)



▲ Figure 7. Impedance versus frequency for an ATC100A101 (100 pF).

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(R. Fiore, *Microwave and Wireless Applications*, May 2001) ₁₂

Lumped Inductors

The most common implementation of inductors in RF and microwave applications are:

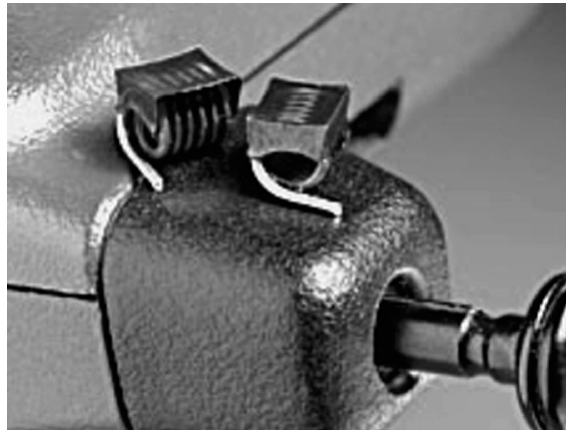
- Wire-wound SMT inductors
- Flat spiral inductors

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Lumped Inductors (cont)

- Wire-wound SMT inductors:
 - Inductance value range: 1nH – 1mH
 - Standard sizes: from 30mil×60mil to 180mil×120mil

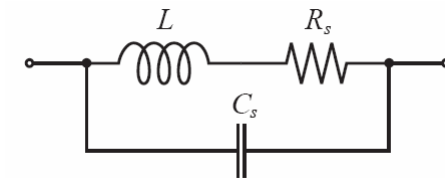


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(A. Batting and P. Brennan, RF Circuit Design, Prentice Hall, 2000),₄

Lumped Inductors (cont)

Simplified model for wire-wound SMT inductors

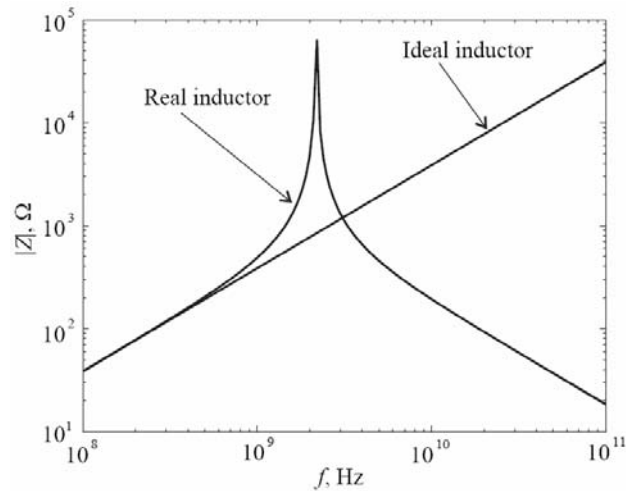


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(*R. Ludwig and P. Bretchko, RF Circuit Design, Prentice Hall, 2000*)₁₅

Lumped Inductors (cont)

Typical performance of SMT inductors

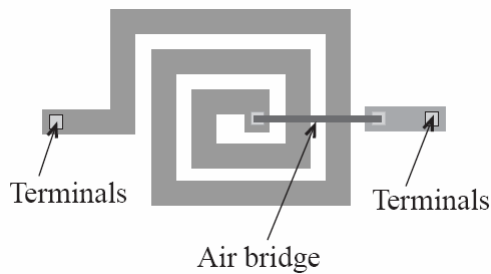


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(*R. Ludwig and P. Bretchko, RF Circuit Design, Prentice Hall, 2000*)₁₆

Lumped Inductors (cont)

- Flat spiral inductors
 - Can be built on PCBs (FR4 substrate) or within an integrated circuit (silicon substrate)
 - Inductance value range: 0.5nH – 500nH
 - Standard sizes: smaller than 2mil×2mil

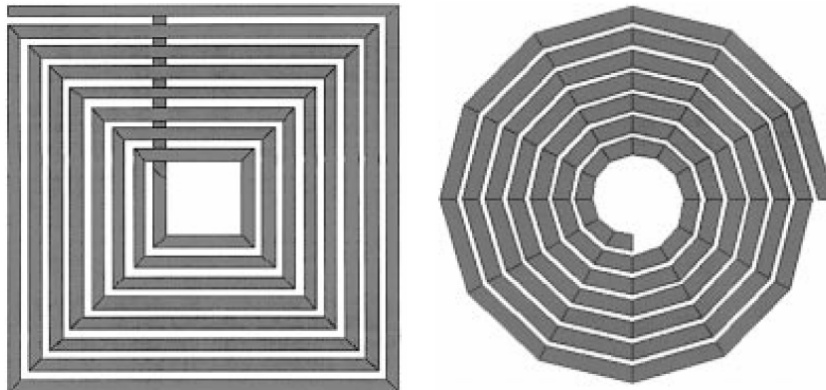


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(R. Ludwig and P. Bretchko, *RF Circuit Design*, Prentice Hall, 2000)₁₇

Lumped Inductors (cont)

Typical geometries for spiral inductors

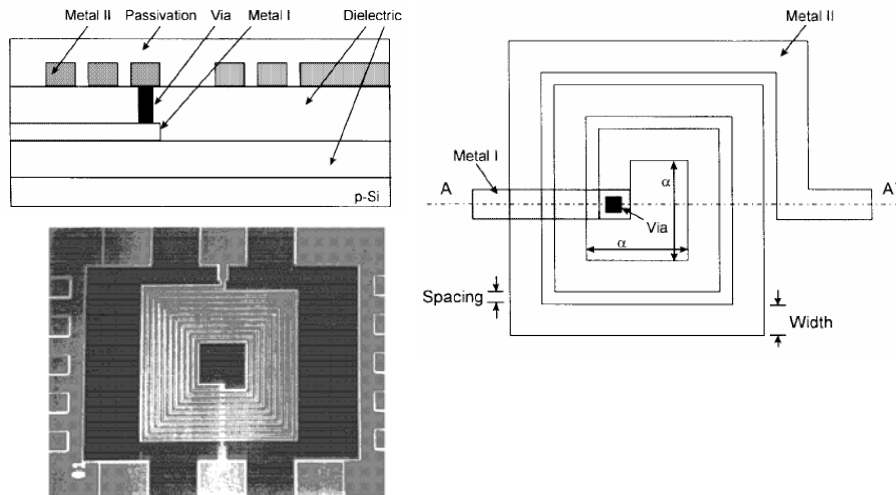


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(A. M. Niknejad, 1998)₁₈

Lumped Inductors (cont)

- Flat spiral inductors on silicon (CMOS technology)

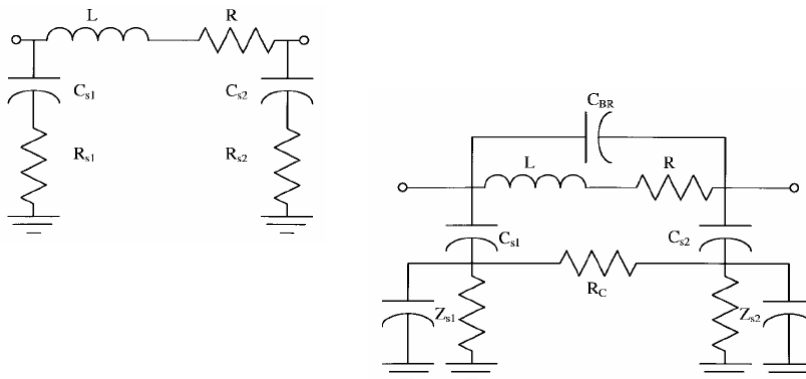


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(M. Park, 1998) ¹⁹

Lumped Inductors (cont)

Equivalent circuit models for flat spiral inductors on silicon



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(A. M. Niknejad, 1998) ²⁰

Lumped Inductors (cont)

Circuit model for several CMOS spiral inductors
obtained from curve fitting

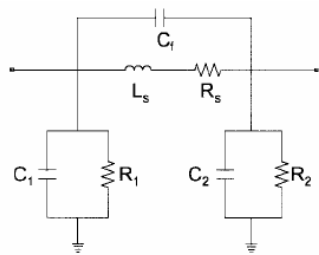


TABLE I
SUMMARY OF EXTRACTED EQUIVALENT CIRCUIT MODEL PARAMETERS FOR
THE VARIOUS KINDS OF RECTANGULAR SPIRAL INDUCTORS WITH THE
DIFFERENT N AT INNER DIAMETER OF $100\ \mu\text{m}$. THE METAL WIDTH
AND SPACING OF INDUCTORS ARE 10 AND $2\ \mu\text{m}$, RESPECTIVELY

N	L_s (nH)	R_s (Ω)	C_r (fF)	C_1 (fF)	C_2 (fF)	R_1 (K Ω)	R_2 (K Ω)
12	34.03	32.49	35.3	40.3	82.4	3.71	1.84
10	22.05	26.31	31.4	26.2	52.7	5.49	3.26
8	13.10	19.26	25.6	20.9	37.1	7.11	5.97
6	6.84	13.06	18.0	15.5	23.0	6.63	5.57
4	2.85	7.87	9.0	12.6	14.8	12.26	18.78