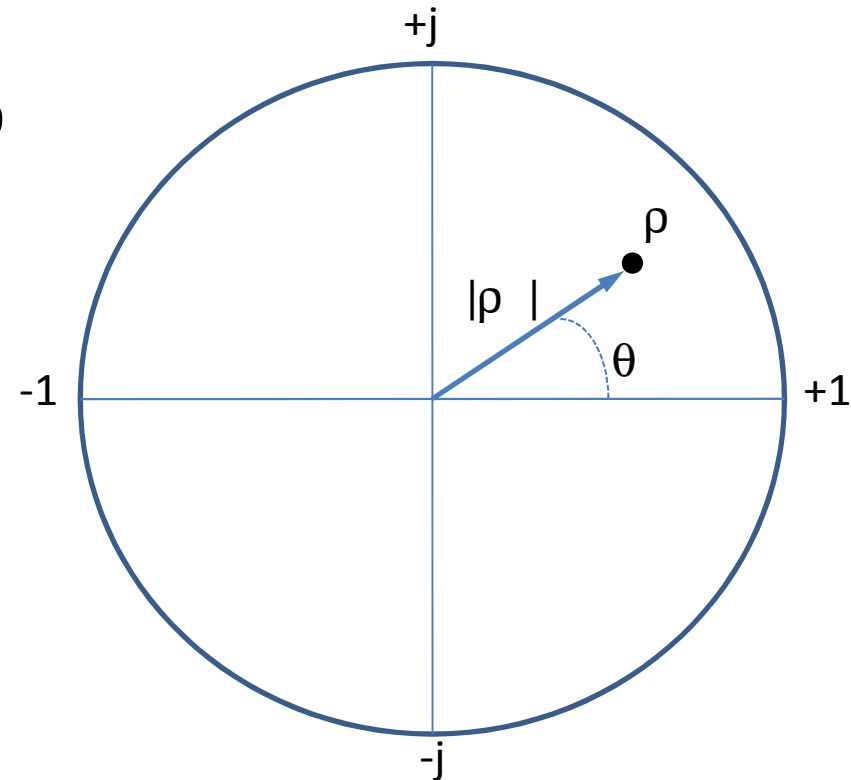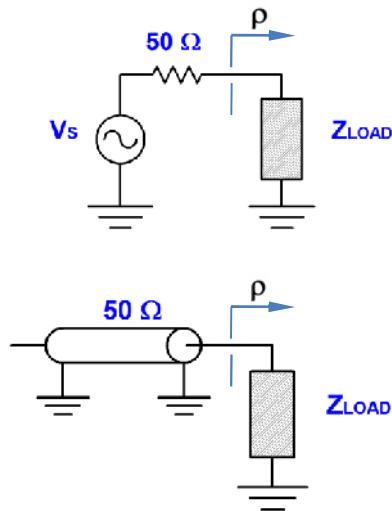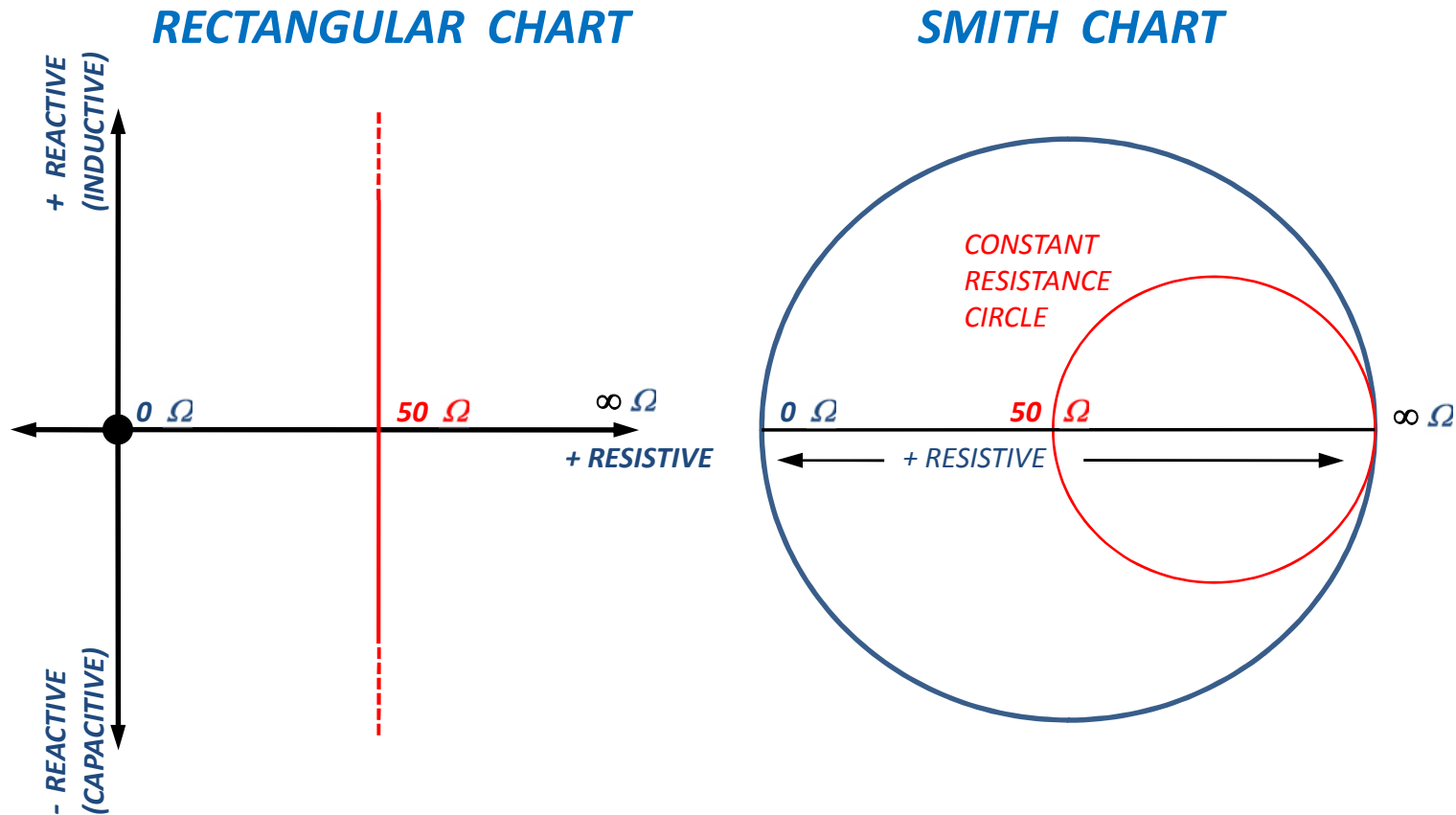# Smith Chart
Lumped Element Z-Matching
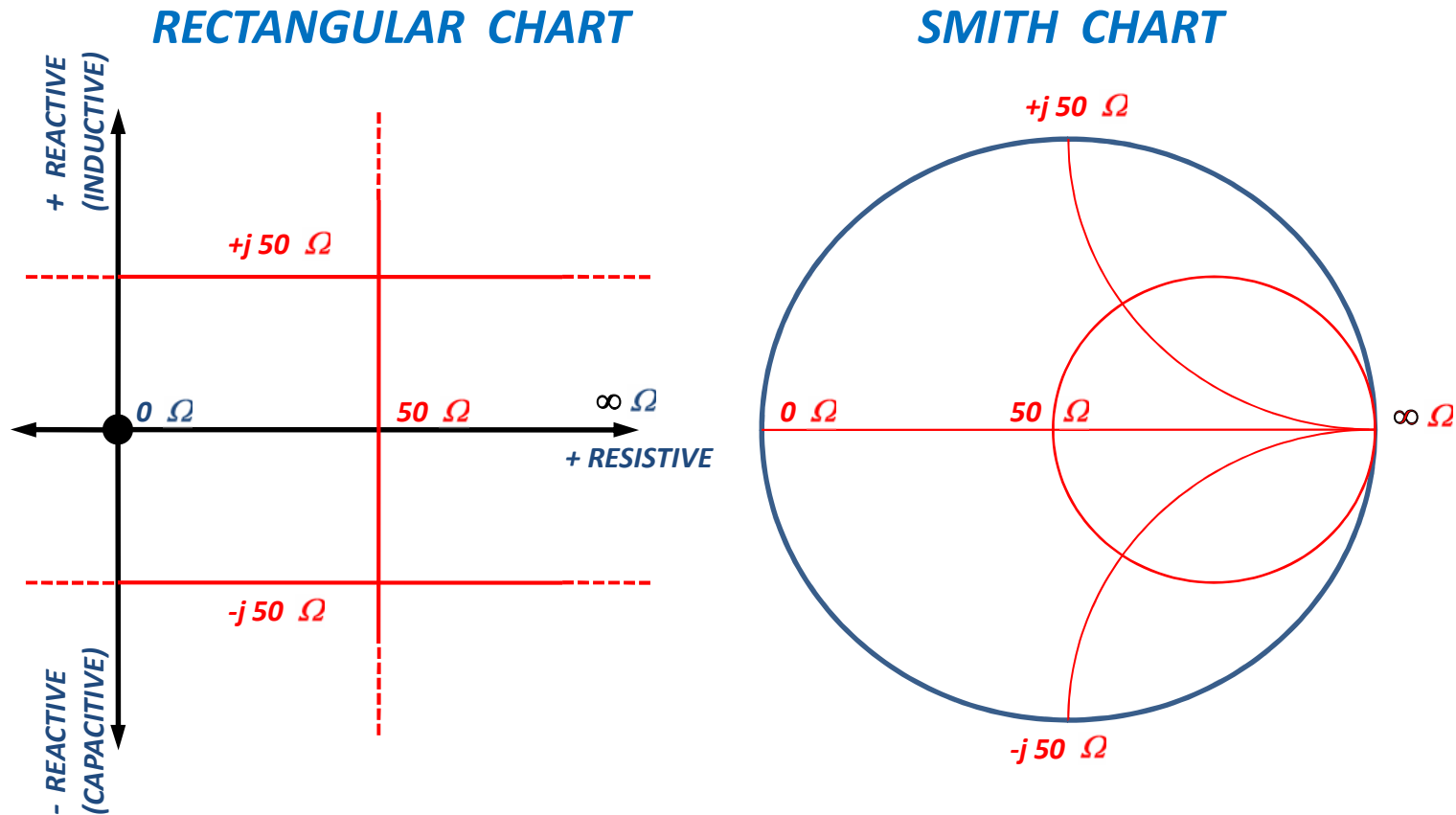
Origin of the Smith Chart

REFLECTION COEFFICIENT: ρ

- ρ IS RATIO OF REFLECTED TO FORWARD VOLTAGE AT LOAD

- ρ IS COMPLEX NUMBER: (REAL, IMAGINARY) or (MAGNITUDE, ANGLE)

- |ρ| =1.0 IS MAXIMUM POSSIBLE WITH PASSIVE LOAD (TOTAL REFLECTION)

- |ρ| =1.0 CIRCLE IS OUTER BOUNDARY OF STANDARD SMITH CHART

Impedance View – Constant Resistance

RECTANGULAR CHART

+ REACTIVE (INDUCTIVE)

0 Ω

50 Ω

∞ Ω

+ RESISTIVE

- REACTIVE (CAPACITIVE)

SMITH CHART

CONSTANT RESISTANCE CIRCLE

0 Ω

50 Ω

∞ Ω

+ RESISTIVE

- $Z = R + j X$
- IMPEDANCE HAS A REAL PART AND AN IMAGINARY PART
- IMPEDANCE REPRESENTS A SERIES CONNECTION
- CONSTANT REAL LINES BECOME CIRCLES ON SMITH CHART

K5TRA

Impedance View – Constant Reactance

RECTANGULAR CHART

SMITH CHART

- CONSTANT REACTANCE LINES BECOME ARCS ON SMITH CHART
- UPPER HALF IS INDUCTIVE
- LOWER HALF IS CAPACITIVE
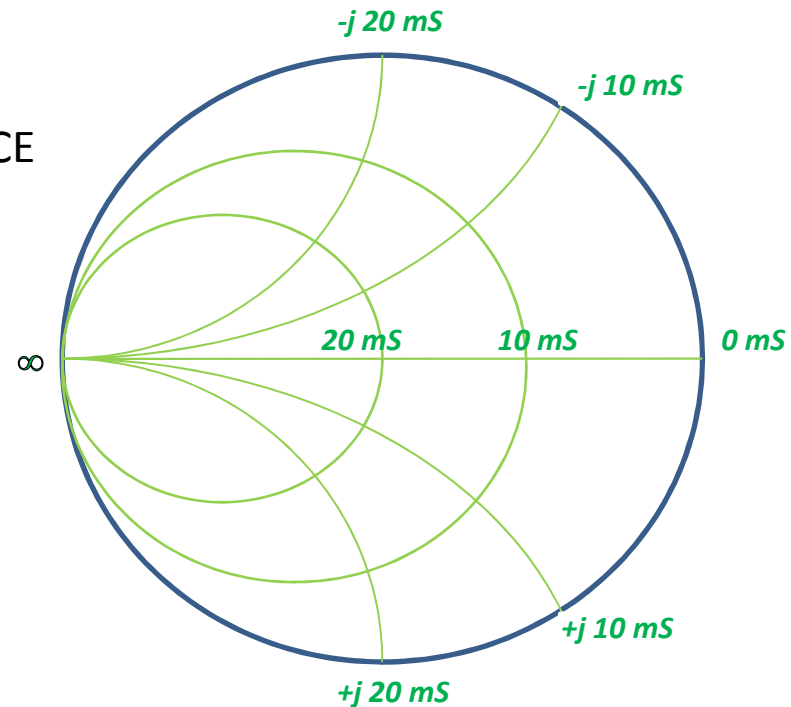- POSITIVE REAL IS INSIDE THE SMITH UNIT CIRCLE

K5TRA

Impedance View

RECTANGULAR CHART
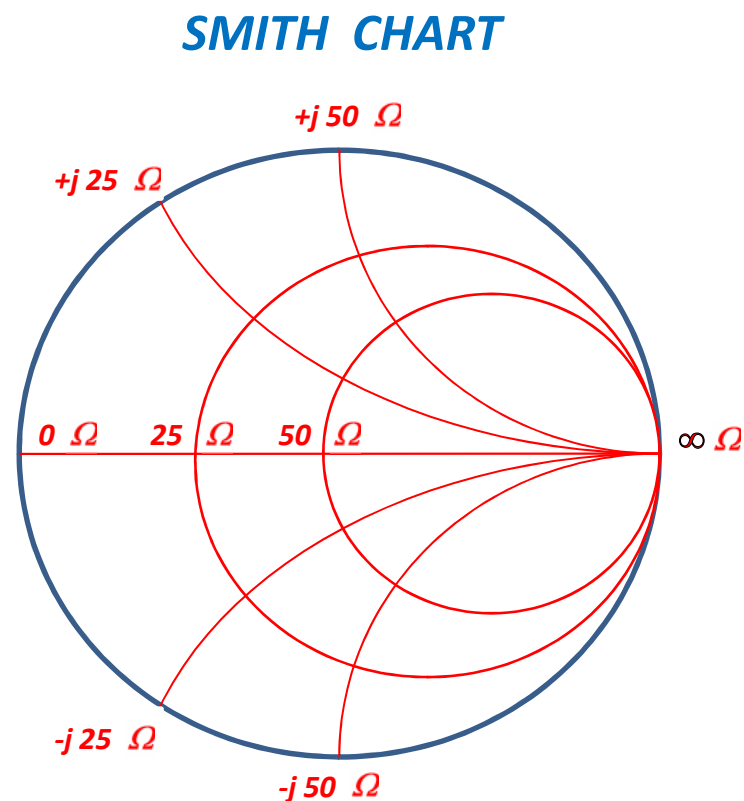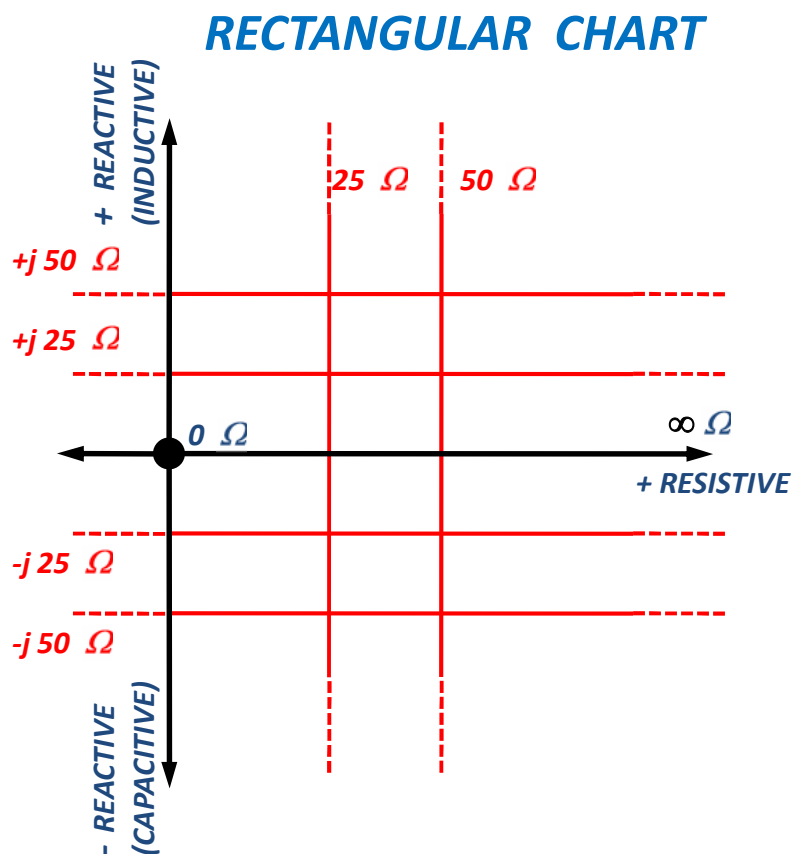
SMITH CHART

- IMPEDANCE REPRESENTATION OF THE SMITH CHART
- USUALLY IN RED
- LOWER HALF IS CAPACITIVE
- POSITIVE REAL IS INSIDE THE SMITH UNIT CIRCLE

**K5TRA**

T.Apel

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Admittance View

- **Y = 1/Z = G + j B**
- ADMITANCE IS RECIPROCAL IMPEDANCE
- ADMITANCE REPRESENTS A PARALLEL CONNECTION

- ADMITANCE HAS A REAL PART (CONDUCTANCE) AND AN IMAGINARY PART (SUSCEPTANCE)
- CONSTANT CONDUCTANCE IS A CIRCLE ON SMITH CHART
- CONSTANT SUSCEPTANCE IS AN ARC ON SMITH CHART

K5TRA

OVERLAY SMITH CHART

- BOTH IMPEDANCE AND ADMITANCE VIEWS OF SAME POINT

- SIMULTANEOUS VIEW OF SERIES IMPEDANCE OR PARALLEL ADMITTANCE

- THIS VIEW PROVIDES A CONVENIENT WAY TO DESIGN LUMPED ELEMENT MATCHING NETWORKS
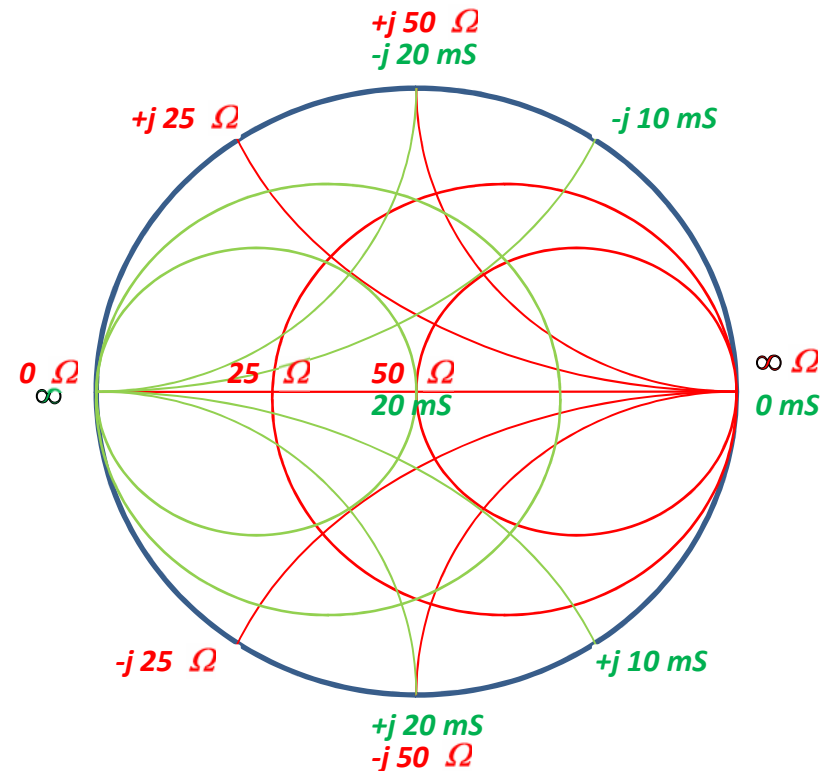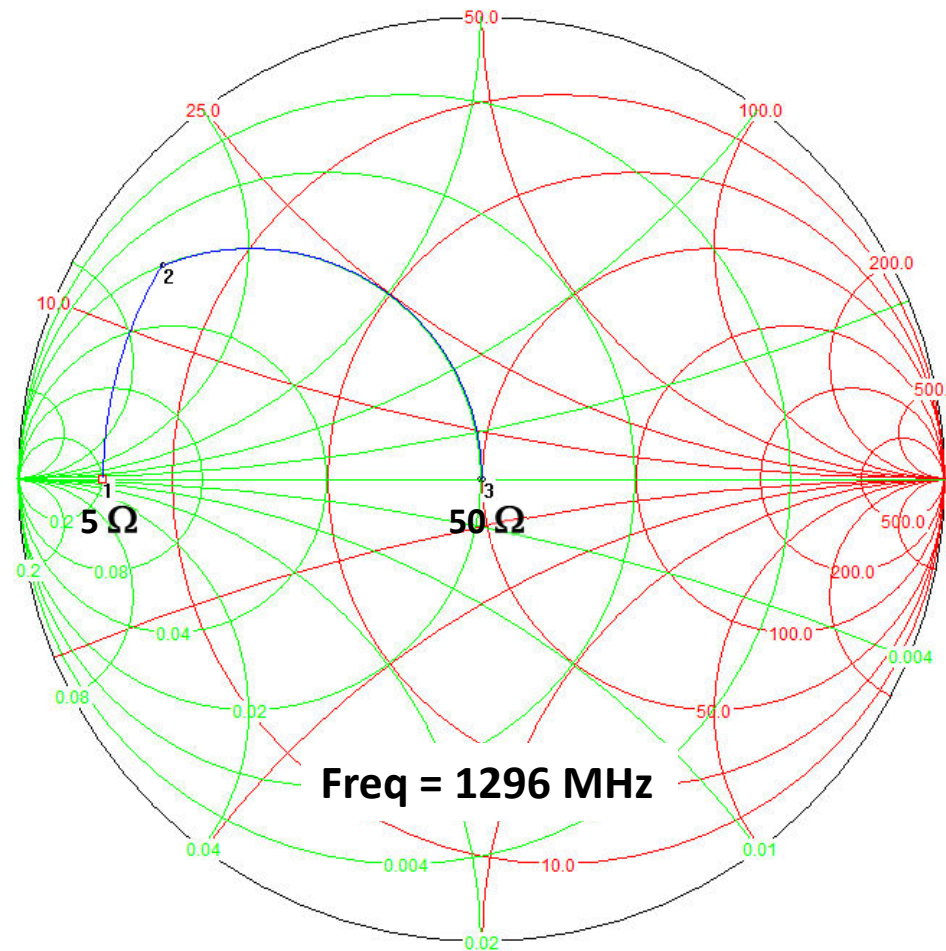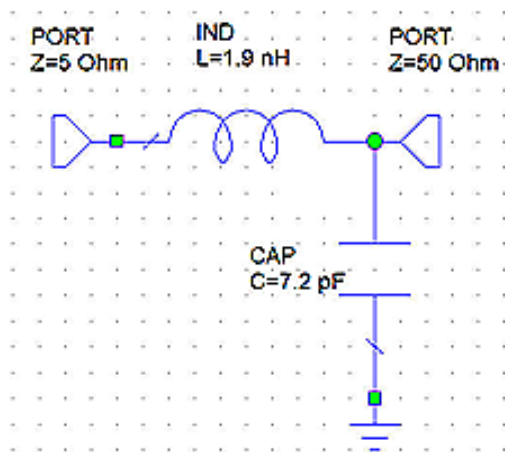
Lumped Element Z-Matching

- A SIMPLE EXAMPLE IS TO MATCH BETWEEN 25 Ω AND 50 Ω

- FROM THE 25 Ω POINT WE FIRST USE THE IMPEDANCE VIEW TO MOVE TO EITHER POINT *B* OR *C*

- THE (+) REACTIVE SHIFT FROM *A* TO *B* REPRESENTS A SERIES INDUCTOR

- THE (-) REACTIVE SHIFT FROM *A* TO *C* REPRESENTS A SERIES CAPACITOR

- NOTE THAT BOTH *B* and *C* ARE ON THE 20 mS CIRCLE. THIS ALLOWS US TO REACH 50 Ω WITH A SHUNT ELEMENT
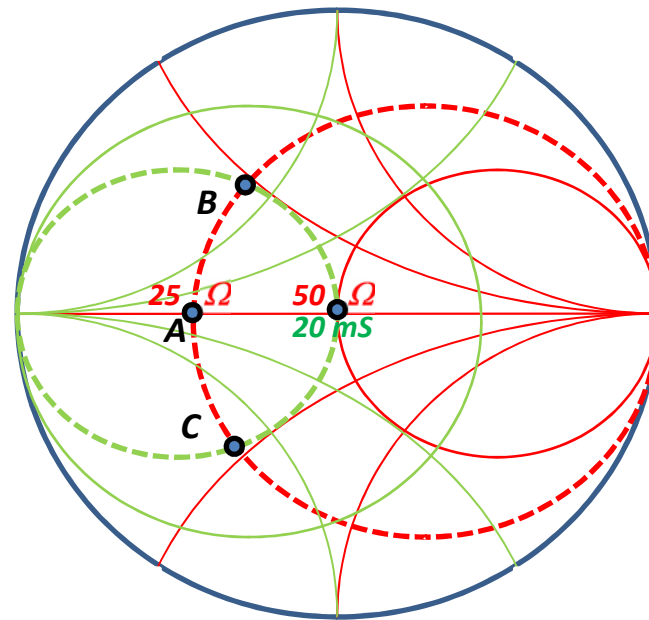
➢ THROUGH *B* REQUIRES SERIES INDUCTOR AND SHUNT CAPACITOR
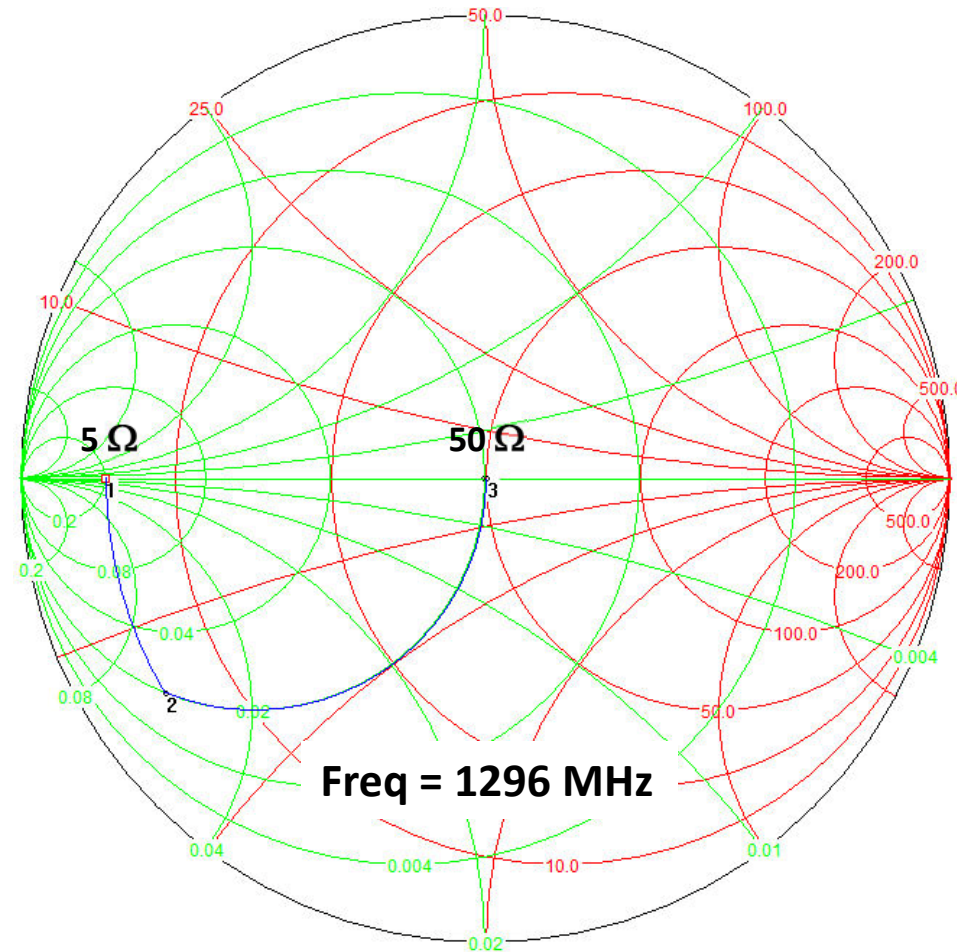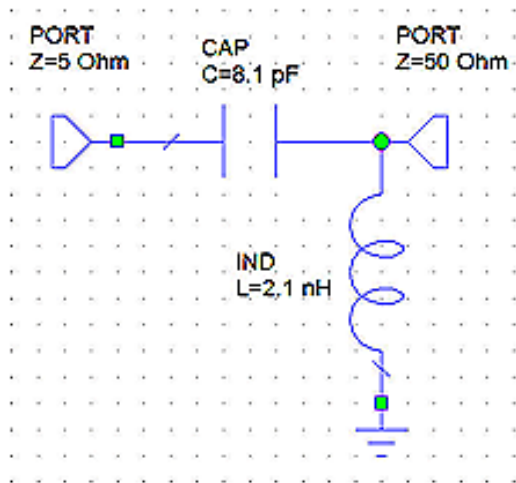
➢ THROUGH *C* REQUIRES SERIES CAPACITOR AND SHUNT INDUCTOR

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Examples: LP

- 5 Ω to 50 Ω MATCH
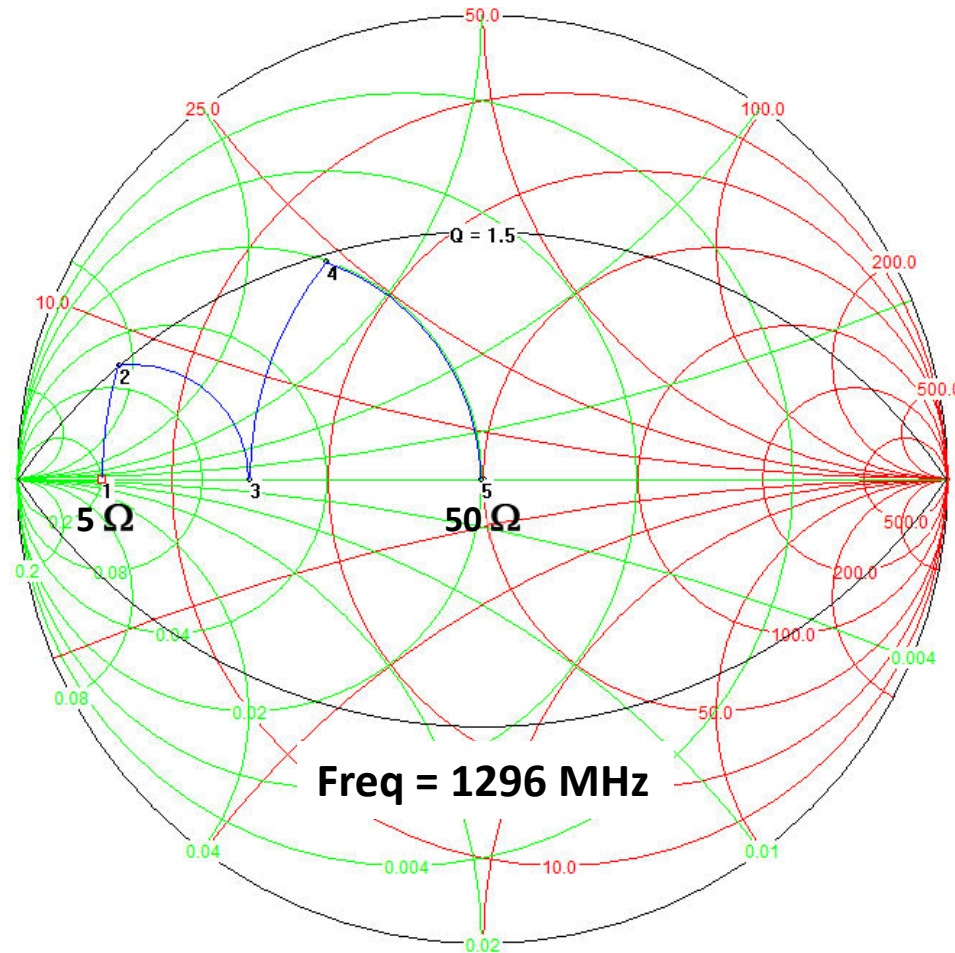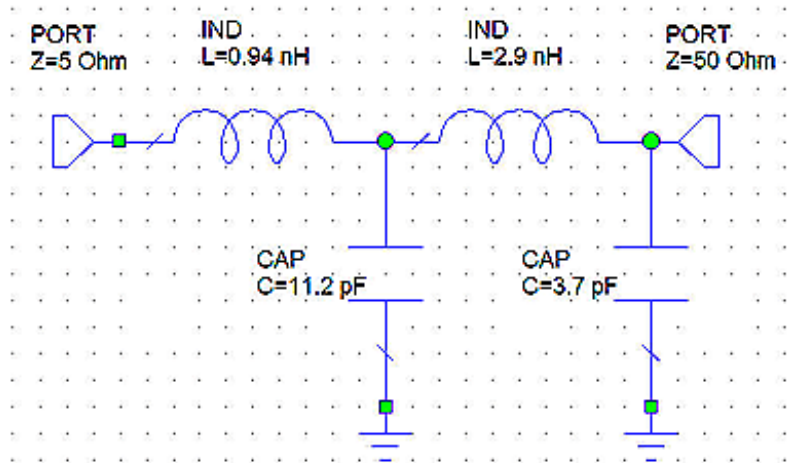
- N=2 :   SERIES L   SHUNT C

- LOWPASS ELEMENTS

PORT
Z=5 Ohm

IND
L=1.9 nH

PORT
Z=50 Ohm

CAP
C=7.2 pF

5 Ω

50 Ω

Freq = 1296 MHz

Examples : HP

- 5 Ω to 50 Ω MATCH

- N=2 : SERIES C SHUNT L

- HIGHPASS ELEMENTS

PORT
Z=5 Ohm

CAP
C=8.1 pF

PORT
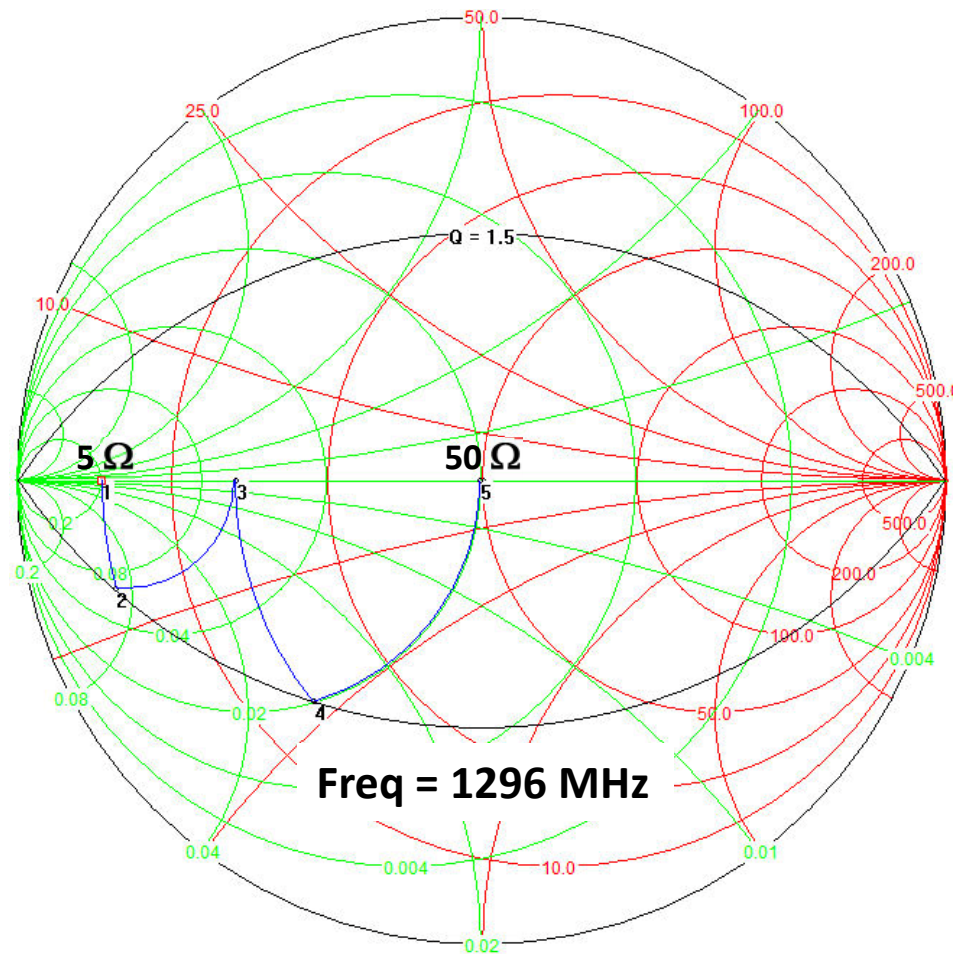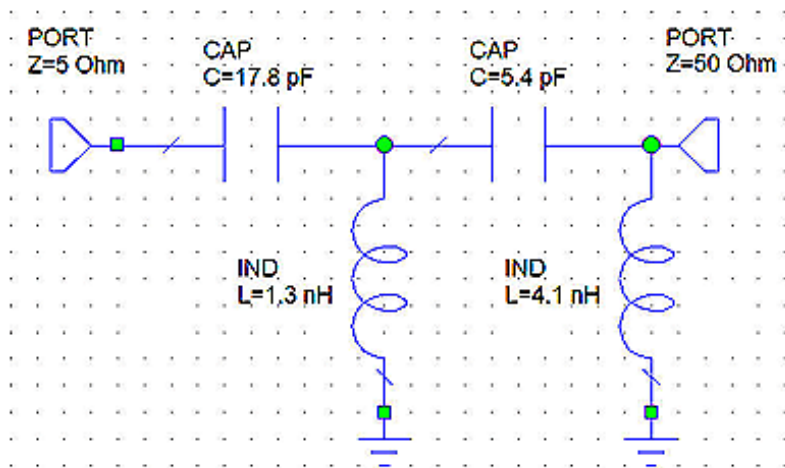Z=50 Ohm

IND
L=2.1 nH

5 Ω   50 Ω

Freq = 1296 MHz

Examples : LPLP

- 5 Ω to 50 Ω MATCH

- N=4 : SERIES L SHUNT C SERIES L SHUNT C

- LOWPASS ELEMENTS

PORT
Z=5 Ohm

IND
L=0.94 nH

IND
L=2.9 nH

PORT
Z=50 Ohm

CAP
C=11.2 pF

CAP
C=3.7 pF

5 Ω   50 Ω

Freq = 1296 MHz

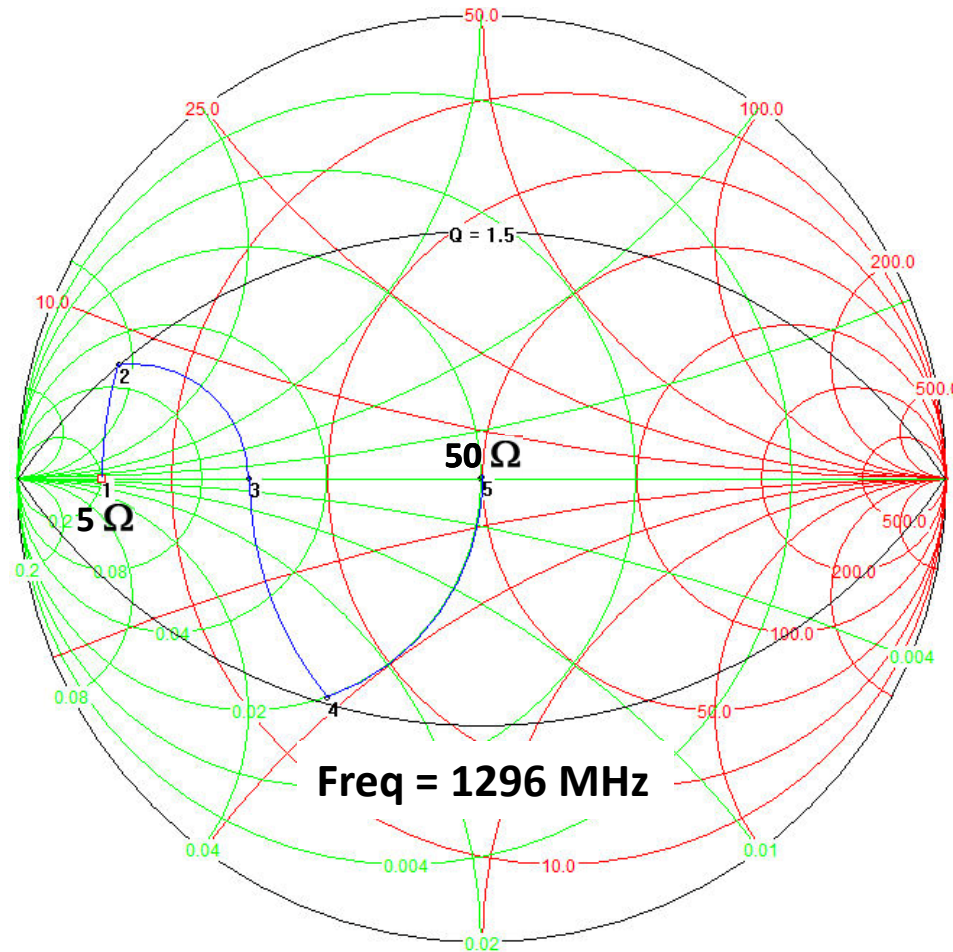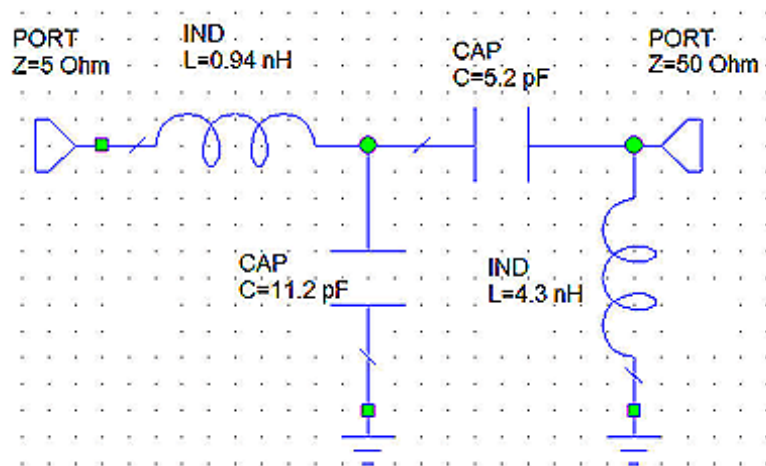# Examples : HPHP

- 5 Ω to 50 Ω MATCH

- N=4 : SERIES C SHUNT L SERIES C SHUNT L
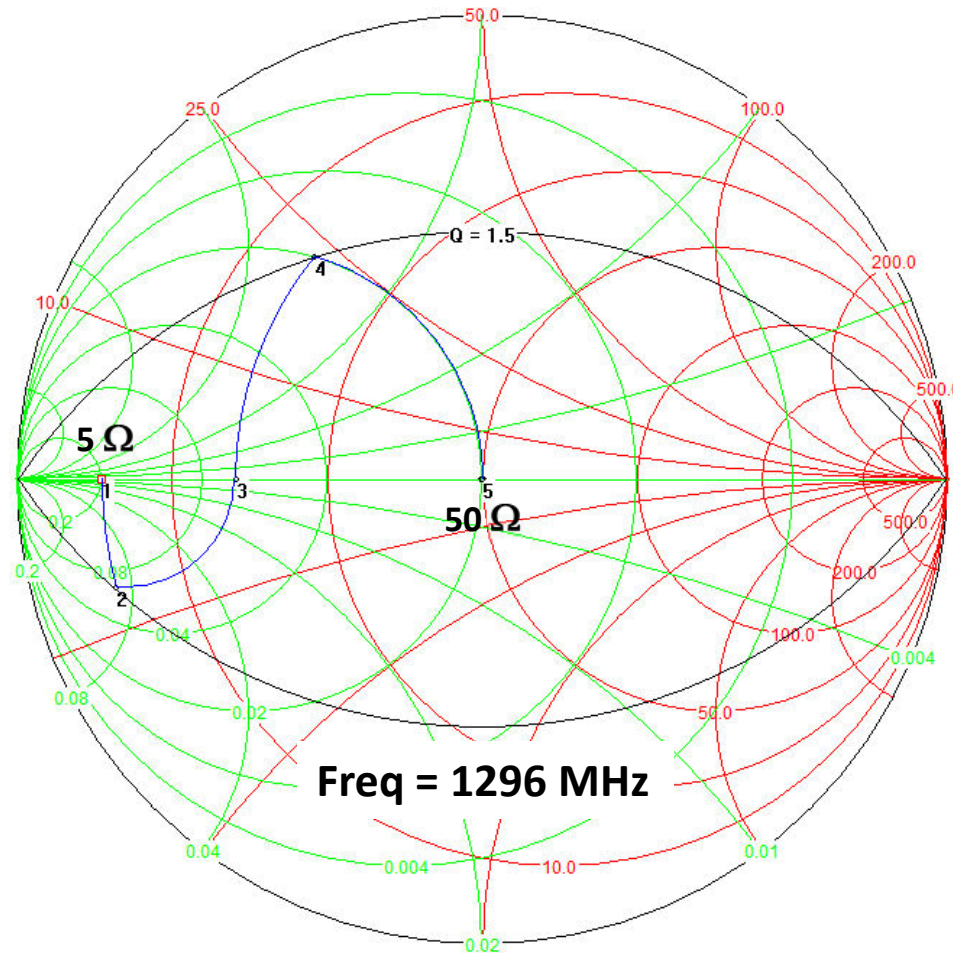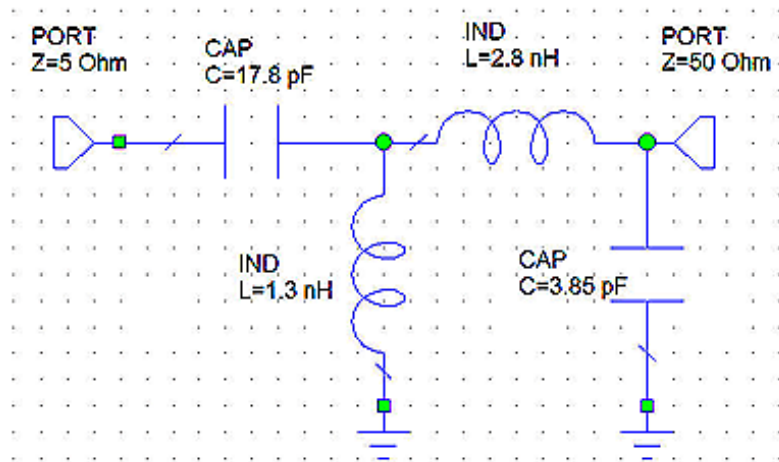
- HIGHPASS ELEMENTS

Freq = 1296 MHz

Examples : LPHP

- 5 Ω to 50 Ω MATCH

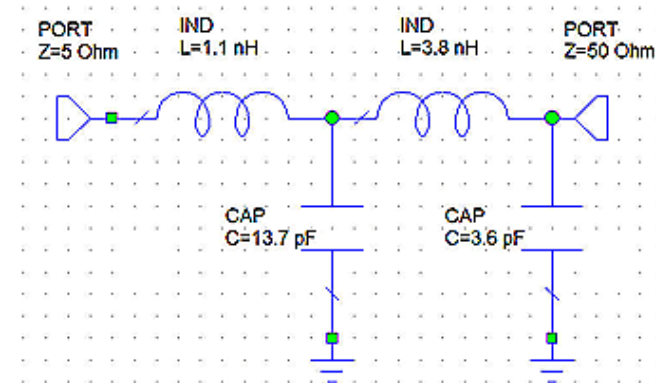- N=4 : SERIES L SHUNT C
  SERIES C   SHUNT L

- BANDPASS ELEMENTS

PORT
Z=5 Ohm

IND
L=0.94 nH

CAP
C=5.2 pF

PORT
Z=50 Ohm

CAP
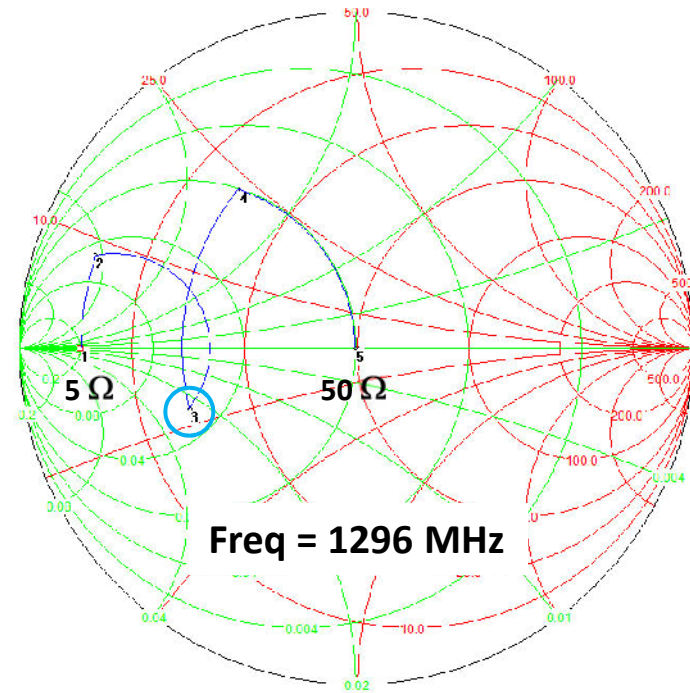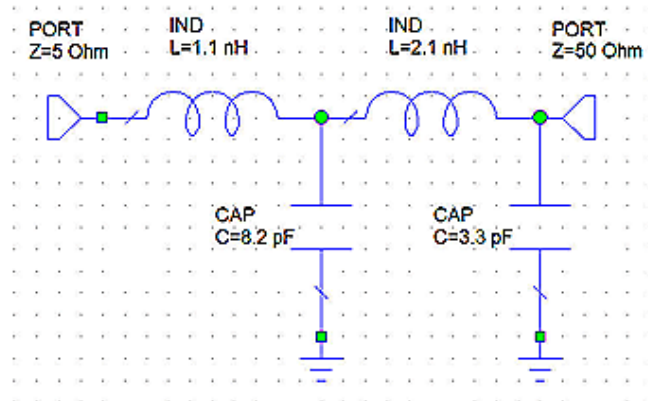C=11.2 pF

IND
L=4.3 nH

50 Ω

5 Ω

Freq = 1296 MHz

Examples : HPLP

- 5 Ω to 50 Ω MATCH

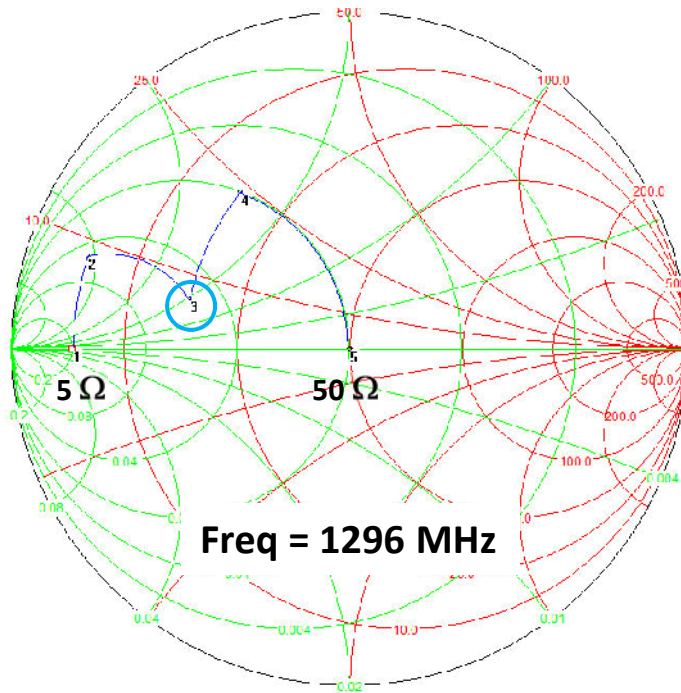- N=4 : SERIES C SHUNT L SERIES L SHUNT C

- BANDPASS ELEMENTS

PORT Z=5 Ohm
CAP C=17.8 pF
IND L=2.8 nH
PORT Z=50 Ohm
IND L=1.3 nH
CAP C=3.85 pF

5 Ω
50 Ω

Freq = 1296 MHz

Different Internal Z

Freq = 1296 MHz

5 Ω   50 Ω

PORT Z=5 Ohm   IND L=1.1 nH   IND L=2.1 nH   PORT Z=50 Ohm

CAP C=8.2 pF   CAP C=3.3 pF

Freq = 1296 MHz

5 Ω   50 Ω

PORT Z=5 Ohm   IND L=1.1 nH   IND L=3.8 nH   PORT Z=50 Ohm

CAP C=13.7 pF   CAP C=3.6 pF

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LOSS CONSIDERATIONS

$I1 > I2 > I3$

$Z1 < Z2 < Z3$

Z1   Z2   Z3
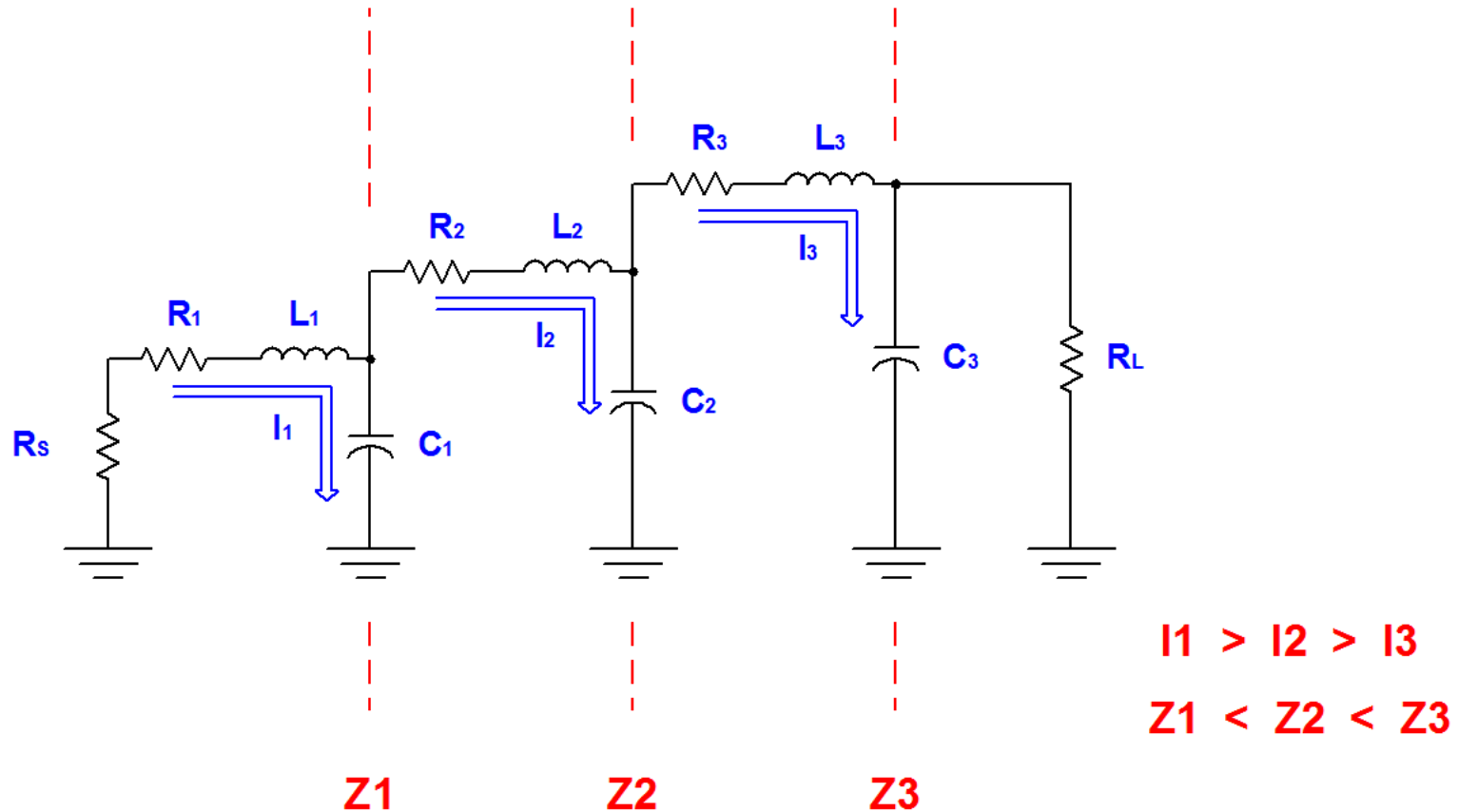
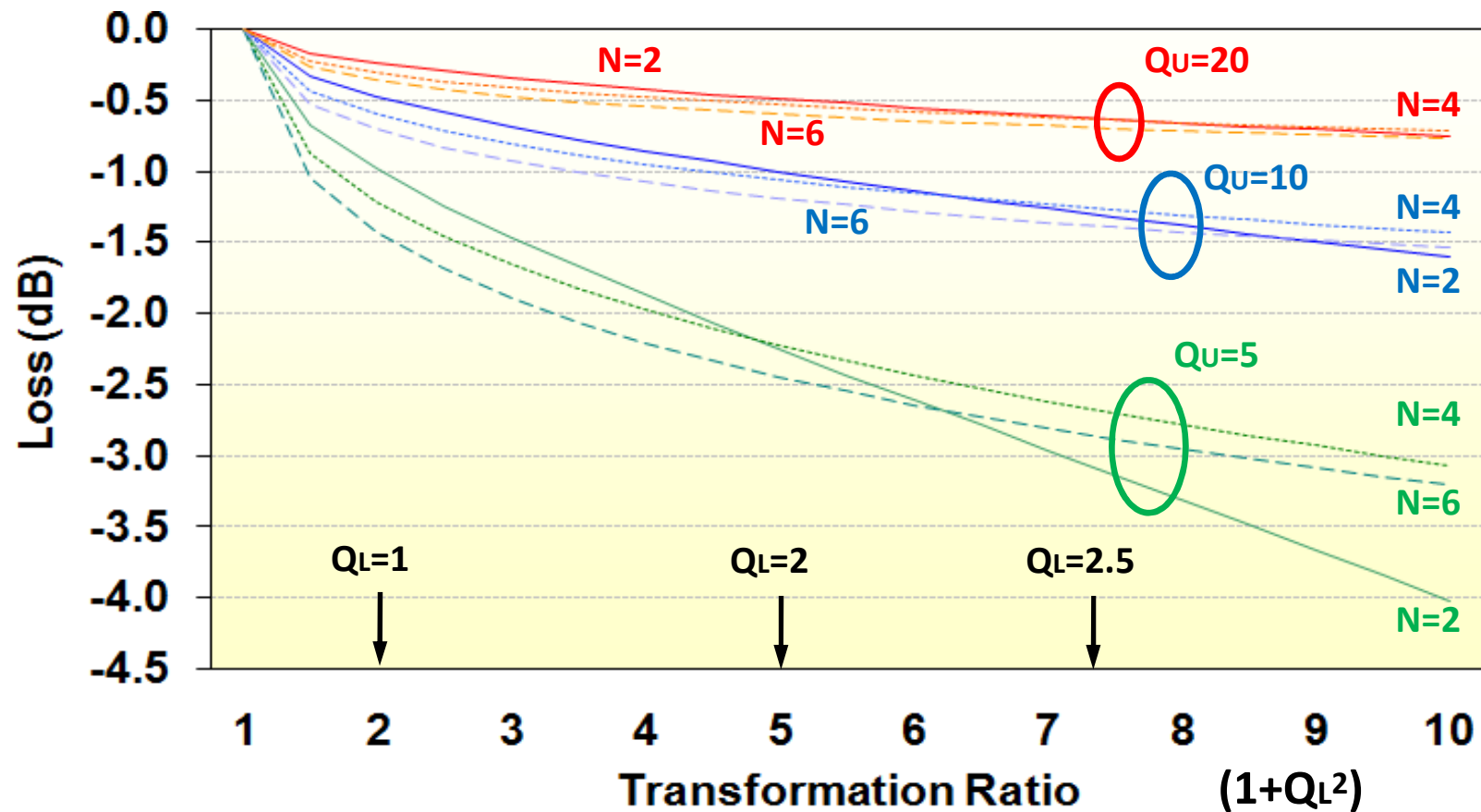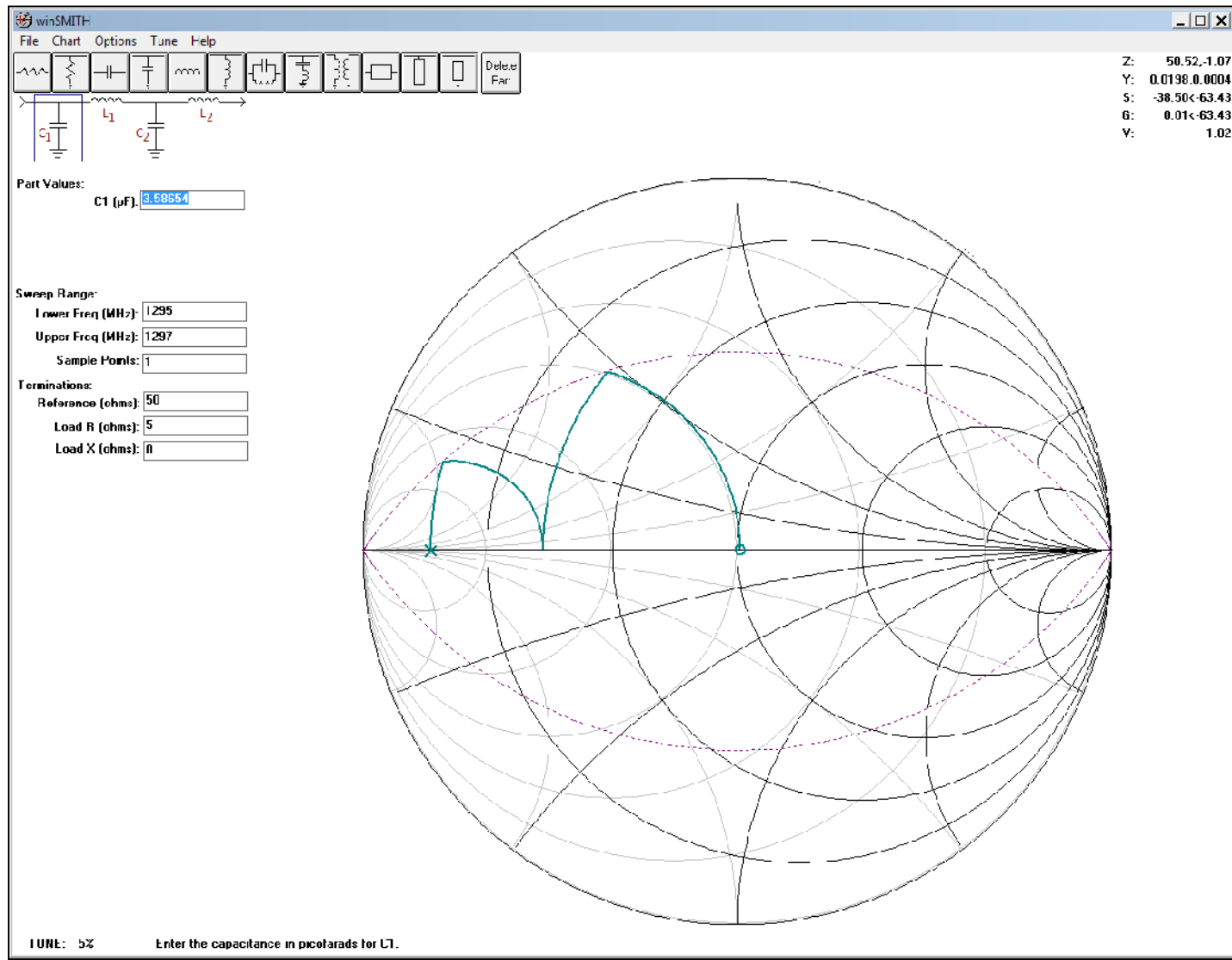**Power transfer of each section is $Q_U / (Q_U - Q_L)$**

Z transformation $\Rightarrow$ $Q_L > 1$ $\Rightarrow$ I increases as Q_L^2 $\Rightarrow$ $I^2 R$ LOSSES!

LOSS TRADE-OFFS

Software Tools: *winSMITH*

Software Tools: *SMITH*