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

**Reflection Coefficient:** \( \rho \)

- \( \rho \) is the ratio of reflected to forward voltage at load.
- \( \rho \) is a complex number: (real, imaginary) or (magnitude, angle).
- \(|\rho| = 1.0\) is maximum possible with passive load (total reflection).
- \(|\rho| = 1.0\) circle is the outer boundary of the standard Smith chart.
Impedance View – Constant Resistance

- **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
Impedance View – Constant Reactance

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

- **RECTANGULAR CHART**
  - + REACTIVE (INDUCTIVE)
  - +j 50 Ω
  - +j 25 Ω
  - 0 Ω
  - -j 50 Ω
  - -j 25 Ω
- **SMITH CHART**
  - +j 50 Ω
  - +j 25 Ω
  - 0 Ω
  - -j 25 Ω
  - -j 50 Ω

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

- \( Y = \frac{1}{Z} = G + j B \)
- 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
• 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
Examples: LP

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

Freq = 1296 MHz
Examples : HP

• $5 \Omega$ to $50 \Omega$ MATCH
• $N=2$ : SERIES C SHUNT L
• HIGHPASS ELEMENTS

Freq = 1296 MHz
Examples: LPLP

- 5 Ω to 50 Ω MATCH
- N=4: SERIES L SHUNT C
- SERIES L SHUNT C
- LOWPASS ELEMENTS

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

Freq = 1296 MHz
Examples: HPLP

- 5 Ω to 50 Ω MATCH
- N=4: SERIES C  SHUNT L  SERIES L  SHUNT C
- BANDPASS ELEMENTS

Freq = 1296 MHz
Different Internal Z

Freq = 1296 MHz

PORT Z=5 Ohm
IND
L=1.1 nH

PORT Z=50 Ohm
IND
L=2.1 nH

PORT Z=5 Ohm
IND
L=1.1 nH

PORT Z=50 Ohm
IND
L=3.8 nH

CAP
C=8.2 pF

CAP
C=3.3 pF

CAP
C=13.7 pF

CAP
C=3.6 pF
• Power transfer of each section is \( \frac{Q_U - Q_L}{Q_U} \)
• Impedance transformation requires \( Q_L > 1 \)
• Z transformation per section is \( 1 + Q_L^2 \)
• \( I^2 R \) losses (primarily in inductors) produces insertion loss

\[ I_1 > I_2 > I_3 \]
\[ Z_1 < Z_2 < Z_3 \]
LOSS TRADE-OFFS

Loss (dB) vs Transformation Ratio

- N=2
- N=4
- N=6

Q_L=1
Q_L=2
Q_L=2.5

(1+Q_L^2)
Software Tools: **winsMITH**
Software Tools: **SMITH**