L-match example

- **Insertion Loss**
  - component Q

- **Pi & T matches**
  - Smith
  - Reactor

- **Tapped cap/inductor**
  - Antennas, power, phased cap

**Talking about matching networks**

- Facilitate power Xfer by reducing $S_{11} = S_{22}$

- Do so by exploiting resonant impedance Xforms — high V@ resonance

- Mathematical tool: Series to parallel Xform

- Depends on understanding $Q + Z_0 = \sqrt{L/C}$ of 2nd order system

- Only works @ resonance

- **Settled on L-match**

  ![L-match circuit](image)

  - Upward transformer

- Can see w/ series-parallel transform formulas

  $$R_p = R_s \left( Q^2 + 1 \right) \quad \text{and} \quad X_p = X_s \left( \frac{Q^2 + 1}{Q^2} \right)$$

  - Use to make circuit into 2$^{nd}$ order RLC

- $Q$ is defined as $X_s / R_s$ or $X_p / R_p$ — don’t need 2$^{nd}$ order to define $Q$

**Make this concrete & compare to Smith**

![Example circuit](image)

1. Grad/s signal

2. Smith

3. $Z_{n1} = 0.5$

4. $Z_{n2} = 0.5 + 0.5j$

5. $Y_{n2} = 1 - j$ by Smith

6. $Y_{n3} = 1$

7. Added $\frac{1}{jwC}$ by Smith

8. $\frac{1}{\sqrt{LC}}$

9. $Z_0 = \sqrt{L/C}$

10. $2L = 50 \times 10^{-9}$

11. $C = \frac{1}{1 \times 10^{-9}}$
Inductor (c9) is non-ideal, so it has $\frac{1}{Q}$ too.

L: how does this affect overall $Q$?

\[
P_{\text{in}} = P_{\text{load}} + P_{\text{diss}} = Q \times \text{voltage/current in L at resonance}
\]
\[
\text{So } IL = \frac{P_{\text{in}}}{1 + \frac{P_{\text{diss}}}{P_{\text{load}}}} = \frac{P_{\text{in}}}{P_{\text{in}} - P_{\text{diss}}} = \frac{E_{\text{in/cycle}}}{E_{\text{in/cycle}} - Q}
\]
\[
P_{\text{diss}} = (Q \times \text{component}) \times \text{P}_{\text{load}}
\]

Overall $Q$ limited by lowest $Q = \frac{1}{Q_{\text{tot}}} = \sum \frac{1}{Q_i}$, ideally is not much $Q$

Absorb parasitics into L match or ring them out, start real

Want to set $Q$ and $\omega_0$ independently \(\rightarrow\) T or T networks

- $L_1$ combinations of L-match $\times 2$

- Image resistance
- series to parallel \(R_L(Q_i + 1)\)

- In T-match go to lower $R_L$

- Pick $Q$, then make 2 L-matches
  $\frac{L_i + L_2}{R_i}$ appropriate $\omega_0$

- Tapped L/C transformer
  \(V_i \frac{1}{C_1} \frac{1}{L_1} \frac{1}{R_L} \frac{1}{C_2}
  \]
  \(-\text{let } \frac{C_1}{C_1 + C_2} = k\)
  \(-V_0 = kV_i\)
  \(-\text{power into } R_L \text{ same as from } V_i\)
  \(-\text{so } I_0 = \frac{kV_i}{R_L}\)
  \(-\text{booster!}\)

\[
Z_{\text{in}} = \frac{R_L}{2k}
\]
These matches mostly narrowband. Broadband techniques exist

e.g. multi-stage matches  e.g. tapered t. lines

Can replace w/ microstrip stubs to make appropriate loc

Antennas:

6. How does one know when to be an antenna?

6. Related example:

\[
\begin{align*}
V_0 & \quad \bigcirc \quad kV_0 e^{j\phi} \\
& \quad \downarrow \\
& \quad \downarrow
\end{align*}
\]

- How much power delivered by \( V_0 \)?

\[
\dot{P} = \frac{V_0^2 (1 - k e^{-\phi})}{\omega L}
\]

\[Z_{eq} = \frac{1}{\frac{V_0}{\omega L} (1 - k e^{-\phi})}\]

- real component for \( \phi \neq 0, \pi \)

- Real power delivered to other source ... appears as resistive \( Z \)

Can achieve same effect w/ t. line that is imperfectly termed

\[
\begin{align*}
V_0 & \quad \bigcirc \quad kV_0 e^{j\phi} \\
& \quad \downarrow \\
& \quad \downarrow
\end{align*}
\]

- Perfect term \( \rightarrow \) all power into \( R_0 \)

- Field equivalent is parasitic \( \frac{1}{2} \) \( F \) \( H \bigstar \) \( 3 \)

- Can think of work being done on fields

- Radiation requires sizable phase change \( -l \approx \lambda \)

- Power dissipated carried by ideal conductor = 0 \( \beta/c \times E_0 \)

- Power delivered by \( E \times H \) fields around wire