We are finishing matching networks & starting antennas.

A few matching topics that I need to finish or schedule:

- **π & T networks**

  \[
  C_1 \quad C_2 \quad \parallel \quad R_2 = C_1 \quad \parallel \quad C_2 \quad \parallel \quad R_2
  \]

  To use them to set Q separately, \( R_{in} / R_L \) linked in L-match.

  - Analyze with series-parallel transform:
    \[
    R_P = (Q^2 + 1) R_s
    \]
    \[
    X_P = \frac{Q^2 + 1}{Q^2} \times X_s
    \]
    Parallel R bigger than series Q always \( \rightarrow \) step-up L \( \rightarrow \) step-down.

  - In π step down & then up resistance to intermediate “image resistance”:

  - Can evaluate \( Q_{total} = \frac{X_1 + X_2}{2R_l} = \frac{1}{2} (Q_1 + Q_2) \)

  - \( Q_1 = \sqrt{\frac{R_L}{R_2}} - 1 \) \( \rightarrow \) \( Q_2 = \sqrt{\frac{R_1}{R_S}} - 1 \) \( \rightarrow \) \( Q_{total} \) is \( \frac{1}{2} Q_1 \) \( \rightarrow \) \( Q_{total} \)

  - Pick total Q, then design 2π L-match for \( Q_{total} = Q_1 + Q_2 \).

  - Merge parasitics into matches – e.g.:

  - Or ring them out – e.g.:

  - **Narrow vs. broad match**

  - **Tapped inductor/capacitor**

  \[
  \begin{align*}
  V_{in} & \rightarrow \sin \quad \frac{V_{in}}{C_1} = \sin \quad \frac{V_{in}}{C_2} \\
  C_2 & \quad \parallel \quad R_L \\
  V_0 & = \frac{V_{in}}{C_1 + C_2} = k \times V_{in}
  \end{align*}
  \]

  \[
  R_{in} = \frac{R_L}{k^2} \quad \text{(} k \lt 1 \text{ so cost} \quad \text{of} \quad R_L \text{ value)}
  \]

- **Tapped Inductor or capacitor**

  \[
  P_{in} = R_{in} \times V_{in} \quad \text{and} \quad P_{out} = \frac{V_o^2}{R_L}
  \]
Antennas!

1st topic in comm. systems — concerned w/ on board for 1st 1/2 class

Why do wires decide to radiate?  

Related example: \( V_0 \) \( \text{e}^{\theta \phi} \) \( kV_0 \) \( \phi \)

\[ i = V_0 (1 - ke^{\phi}) \]

\[ Z_{eq} = \frac{1}{j\omega C (1 - ke^{\phi})} \]

How much power drawn from \( V_0 \)?

\( \rightarrow \) real \( Z_{eq} \) implies real power

\( \rightarrow \) can get from \( \frac{1}{2} \text{Re} V^2 I^2 \) too

So suck by \( kV_0 \) source

Can see same effect w/ t. line — delay picture or smith picture

\[ V = V_0 e^{j\beta z} \]

— Real input impedance

— Where does power go?

Resistive component of \( Z \) called radiation resistance

Power dissipated in fields surrounding wire (does work on field of other?)

Poynting Thm: \( P = \frac{1}{2} \text{Re} \mathbf{E} \mathbf{H}^* \)

Aside: how much power in ideal conductor?

\( P = 0 \) \( \mathbf{E} = 0 \) — carried in fields around conductor

Only see radiation for \( k = \lambda \) 1/4 that causes sizeable \( \phi \)

6, antennas come in 1/2, 3/4, 5/8 dimensions
what happens to power after it leaves wire

- Antenna w/ 2 spheres

\[ I_1 A_1 = I_2 A_2 \quad \text{or power buildup/reduction} \]

\[ I_1 \left( \frac{A_1}{A_2} \right) = \frac{4\pi r_1^2}{4\pi r_2^2} = \left( \frac{r_1}{r_2} \right)^2 \quad \text{Intensity falls as } r^2 \]

\[ I \propto \frac{E_1}{2}\hat{z} \quad \Rightarrow \quad |E| \propto \frac{1}{r} \quad \text{Field falls off as } \frac{1}{r} \]

- Field must fall off as \( \frac{1}{r} \), components w/ other fall off must be reactive — can't be real power flow — \( E \propto \frac{1}{r^2} \) + \( H \propto \frac{1}{r^3} \) in near field

- Consider fields around stationary charge

- In far field is \( r \gg \frac{2D^2}{\lambda} \) + \( r \gg D \) + \( r \gg \lambda \)

- Reactive near field until \( r \geq 0.62 \sqrt{\frac{D^3}{\lambda}} \), reactive in between

- Antennas aren't isotropic — represent w/ directivity

- Imagine 2 antennas

\[ P_{\text{Rx}} = \frac{P_{\text{Tx}}}{A_{\text{Rx}}} \cdot A_{\text{Rx}} \cdot D_{\text{Tx}}(\theta) \cdot \frac{1}{2} \]

\( G_{\text{Rx}} \)

\( \frac{P_{\text{Tx}}(\theta)}{EIPD} \)

\( D_{\text{Tx}}(\theta) \)

\( \text{loss in antenna} \)

\( \text{directivity} \)

\( \text{receive aperture} \)

\( \text{Equivalent isotropic power density} \)

\( \text{EIPD} \)

\( A_e = \frac{\lambda^2}{4\pi} G \)

- RX antenna aperture tricky

\[ P_{\text{Rx}} = \frac{P_{\text{Tx}} G_{\text{Tx}} G_{\text{Rx}}}{4\pi} \quad \Rightarrow \quad P_{\text{Rx}} = \frac{P_{\text{Tx}} G_{\text{Tx}} G_{\text{Rx}}}{4\pi r^2} \]

\( \lambda^2 \)

\( \text{called path loss} \)

\( 1.55 \)