Lecture 38

Use Smith Chart for today's four examples.

1 Example 1: VSWR and load impedance

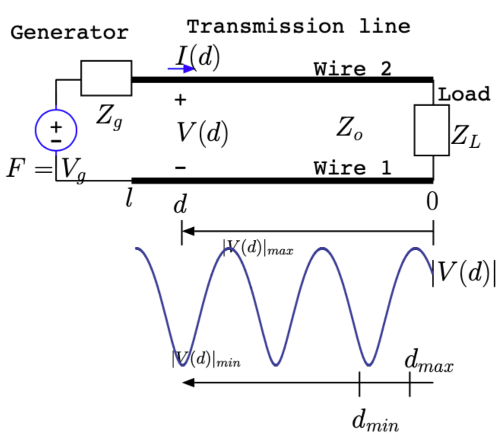
Example 1: An unknown load Z_L on a $Z_o = 50\ \Omega$ TL has $V(d_{min}) = 20$ V, $d_{min} = 0.125\,\lambda$ and $VSWR = 4$.

Determine (a) the load impedance Z_L, and (b) the average power P_L absorbed by the load.

1. $z(d_{max}) = \text{VSWR} = 4$, draw constant $|\Gamma_L|$ circle
2. $d_{min} = 0.125\,\lambda$, rotate towards load (RWL) in counter-clockwise direction with $\frac{\lambda}{8}$ distance → normalized load impedance z_L

2 Example 2: Generator voltage Vg

Example 2: If the TL circuit in Example 1 has $l = 0.625\,\lambda$, and a generator with an internal impedance $Z_g = 50\ \Omega$, determine the generator voltage V_g.



Use voltage division at the generator side.

3 Example 3: Determine V+ and V-

Example 3: Determine V^+ and V^- in the circuit of Examples 1 and 2 above such that the voltage phasor on the line is given by

$$V(d) = V^+ e^{j\beta d} + V^- e^{-j\beta d}$$

Use $|\Gamma_L| = \frac{\text{VSWR}-1}{\text{VSWR}+1} = \Gamma(d_{max}) = -\Gamma(d_{min})$

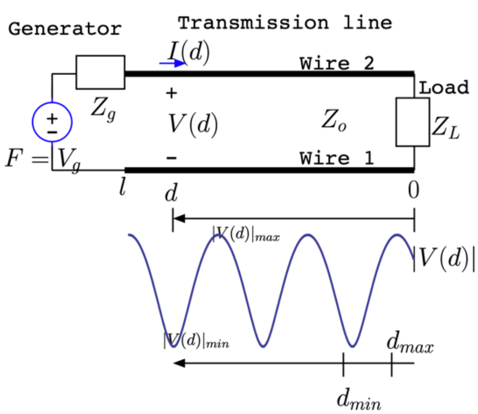
And $V(d_{min}) = V^+ e^{j\beta d_{min}}\left(1 + \Gamma(d_{min})\right)$ to calculate V^+

4 Example 4: Load voltage and current

Example 4: Determine the load voltage and current $V_L = V(0)$ and $I_L = I(0)$ in the circuit of Examples 1-3 above.

5 Impedance match

For the following general TL, the power at any point equals to the power delivered to the load.



In general, power $P(d)$ at distance d away from the load is

$$P(d) = \frac{|V^+|^2}{2Z_o} - \frac{|V^-|^2}{2Z_o}$$

Power $P(d)$ is the difference of the power transported

$\frac{|V^+|^2}{2Z_o}$ is the power by the forward-going wave;

$\frac{|V^-|^2}{2Z_o}$ is the power of the reflected wave.

To maximize the power delivered to the load, we want to design our circuit that $Z_L = Z_o$.

In this way, we say we have matched impedance.

- There is no reflected wave;
- Load reflection coefficient $\Gamma_L = 0$;
- VSWR = 1.

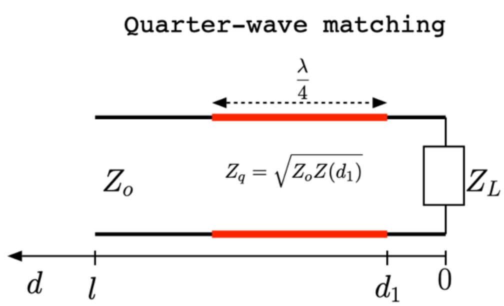
6 Impedance matching method

We consider two ways of achieving an impedance match: Quarter-wave matching and single-stub tuning.

6.1 Quarter-wave matching

6.1.1 Quarter-wave matching of resistive loads

Consider a TL with $Z_L = 25\ \Omega$ and $R_g = Z_o = 50\ \Omega$. Since $Z_L \neq Z_o$, the load is unmatched and the VSWR>1.



We insert a $\lambda/4$ transformer at the $d_1 = 0$ location (at the load terminal).

The purpose of impedance matching is to get the input impedance on the left side of the red line ($d_1 = \lambda/4$ location) $Z(d_1) = Z_o$

The desired characteristic impedance of the red line is

$$Z_q = \sqrt{Z_L Z(d_1)} = \sqrt{Z_L Z_o}$$

6.1.2 Quarter-wave matching of reactive loads

Consider a TL with $Z_L = 50 + j50\ \Omega$ and $R_g = Z_o = 50\ \Omega$. Since $Z_L \neq Z_o$, the load is unmatched and the VSWR>1.

Find position d_1 where to insert the $\lambda/4$ transformer; and the characteristic impedance of the red TL line Z_q.

We insert a $\lambda/4$ transformer at the $d_1 \neq 0$ location (at the load terminal).

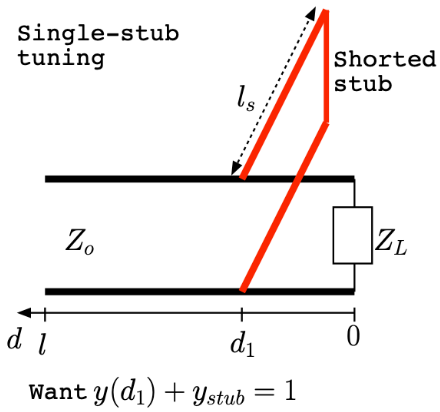
Step 1: We will rotate Z_L towards generator by a distance of d_1, such that $Z(d_1)$ becomes a purely real number.

- Put Z_L on smith chart
- Draw constant $|\Gamma_L|$ circle
- Find the point where constant $|\Gamma_L|$ circle intersects with the horizontal real axis. That is the normalized impedance $z(d_1)$
- Calculate distance d_1 from the smith chart

Step 2: Then we can use the above method to design characteristic impedance of the red TL line.

$$Z_q = \sqrt{Z_L Z(d_1)}$$

- Note: don't forget to denormalize $z(d_1)$ when use the above equation.

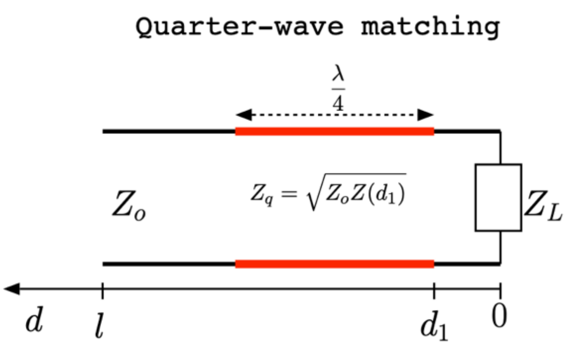


6.2 Single-stub tuning

We will insert a shorted-stub a distance d_1 to the left of the load, in parallel with the line to achieve an impedance match. Note when we have parallel connection, we use admittance Y instead of impedance Z.

- $Y_{parallel} = Y_1 + Y_2$
- Note: we need to use *denormalized admittance for the above equation*, while the admittance we read from smith chart is the normalized admittance. When the two lines have different characteristic impedance, you have to denormalize admittance first, then calculate the parallel admittance.

6.2.1 Single-stub tuning with short ended stub



Consider a TL with $Z_L = 100 - j50\ \Omega$ and $R_g = Z_o = 50\ \Omega$. Since $Z_L \neq Z_o$, the load is unmatched and the VSWR>1.

a) Find position d_1 where to insert the shorted-stub;

b) Calculate normalized admittance $y(d_1)$ for the black TL.

c) Calculate normalized admittance y_{stub} for the red TL.

d) Find the length l_s of the red shorted-stub.

Step 1: We will rotate the load admittance y_L towards generator by a distance of d_1, such that $y(d_1) = 1 + \text{jb}$. (real part is 1)

- d_1 is the cross section location of constant $|\Gamma_L|$ circle and constant $r = 1$ circle. (r is the real part of normalized impedance z)
- d_1 has two possibilities. → Please watch the lecture video to find out where are the two d_1 locations.
- Calculate d_1 and $y(d_1)$

Step 2: The normalized admittance y_{stub} for the red TL is $-jb$.

- For the short-ended stub, the load admittance is $y_{LS} = \infty$
- Rotate y_{LS} towards generator to y_{stub}, to find the length of the red TL l_s.