

## 4. IMPEDANCE MATCHING

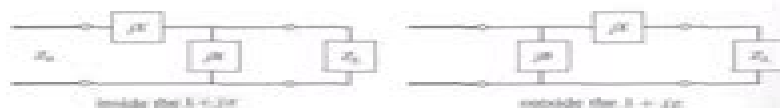
Impedance matching (or tuning) is an important issue for

- Maximum power is delivered when load is matched to line (assuming the generator is matched)
- Power loss is minimized.
- $S/N$  ratio of receiver components is increased.
- Amplitude and phase errors are reduced.

Whenever  $Z_L$  has nonzero real part, impedance matching is possible with the factors such as

- Complexity: Simpler one is preferable.
- Wide Bandwidth: Match a load over a band.
- Implementation: Easier one is preferable
- Adjustability: Adjust to match a variable load impedance.

### 4.1. L Networks Matching

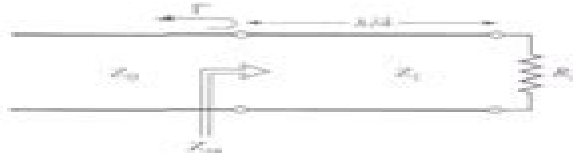


The normalized  $z_L$  should be converted to  $1 + jx$  with adding  $jB$  impedance, then adding  $-jx$  the impedance matching will be successful.

$$\frac{B}{Z_0} = 2\pi fC \Rightarrow C = \frac{B}{2\pi fC Z_0}$$

$$xZ_0 = 2\pi fL \Rightarrow L = \frac{xZ_0}{2\pi f}$$

### 4.2. Quarter Wave Transformer



It is used for only real load impedance. Complex load impedance can always be transformed to real impedance by appropriate length of transmission line. But this generally alters the frequency dependency of the equivalent load reducing the bandwidth of the matching. The following relation has to be satisfied as

$$\Gamma = 0 \Rightarrow Z_{in} = Z_0$$

where

$$Z_{in} = Z_1 \frac{R_L + jZ_1 \tan(kl)}{Z_1 + jR_L \tan(kl)}$$

$$kl = \frac{2\pi \lambda}{\lambda} \frac{\lambda}{4} = \frac{\pi}{2} \Rightarrow Z_{in} = \frac{Z_1^2}{R_L} = Z_0 \Rightarrow Z_1 = \sqrt{Z_0 R_L}$$

For multiple reflection, total  $\Gamma$  is

$$\Gamma = \frac{\Gamma_1 + \Gamma_2 \Gamma_3 \Gamma_1 - \Gamma_1 \Gamma_2 \Gamma_3}{1 + \Gamma_2 \Gamma_3} = \frac{2(Z_1^2 - Z_0 R_L)}{(Z_1 + Z_0)(R_L + Z_1)}$$

The condition of  $\Gamma = 0 \Rightarrow Z_1^2 = Z_0 R_L \Rightarrow Z_1 = \sqrt{Z_0 R_L}$  is also enough to make total reflection (multiple) is zero.

If  $Z_1 = \sqrt{Z_0 R_L}$  and  $l = \lambda/4$ , then  $\Gamma = 0$  and  $SWR = 1$ .

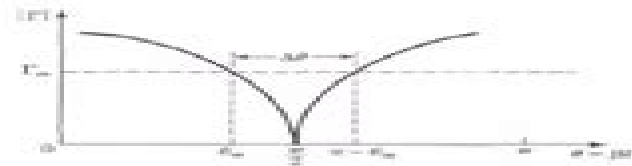


For each frequency,  $l$  has to be equal to  $\lambda/4$ . Thus fixed line length is possible only for one frequency.

- Bandwidth performance of QWT for wide band matching: If one set the maximum value of reflection coefficient,  $\Gamma = \Gamma_m$  that can be tolerated, then the fractional bandwidth is

$$\frac{\Delta f}{f_0} = 2 - \frac{4}{\pi} \arccos \left[ \frac{\Gamma_m}{\sqrt{1 - \Gamma_m^2}} \frac{2\sqrt{Z_0 Z_L}}{|Z_L - Z_0|} \right]$$

This shows that as  $Z_L$  becomes closer to  $Z_0$ , the bandwidth increases. This result is valid only for TEM lines. The step changes of reactance effect can be compensated by making a small adjustment in the length of the matching section. Approximate behavior of reflection coefficients is shown at below.



The QWT can be extended as a multisection form for matching of broader bandwidth.

### 4.3. Single Stub Tuning

A single open-circuited (or short-circuited) transmission line is connected either in parallel or series with the feed line at a certain distance from the load. Single Stub Tuning can match any load impedance to line, but suffer from disadvantage of requiring a variable length between the load and stub.

# Microwave Engineering Lecture Notes

**Inoue-Smith, Yukiko, McVey, Troy**



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