6.3 Quadrature Hybrid or Branchline Coupler

Module:6 Microwave Passive circuits

Course: BECE305L – Antenna and Microwave Engineering

-Dr Richards Joe Stanislaus

Assistant Professor - SENSE

Email: richards.stanislaus@vit.ac.in

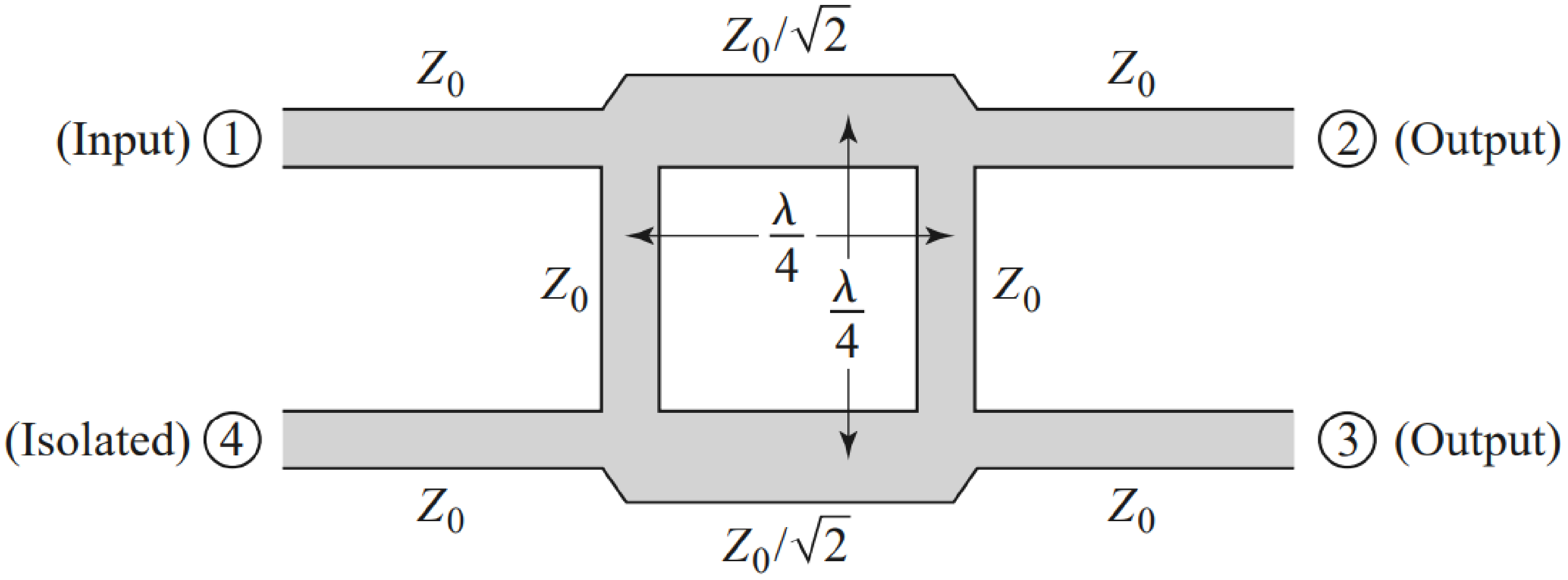
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)
CHENNAI

Module:6 Microwave Passive circuits 7 hours

- T junction and resistive power divider, Wilkinson power divider, branch line coupler (equal & unequal), Rat Race Coupler, Filter design: Low pass filter (Butterworth and Chebyshev) - Richards transformation and stepped impedance methods.
- .
- Source of the contents: Pozar

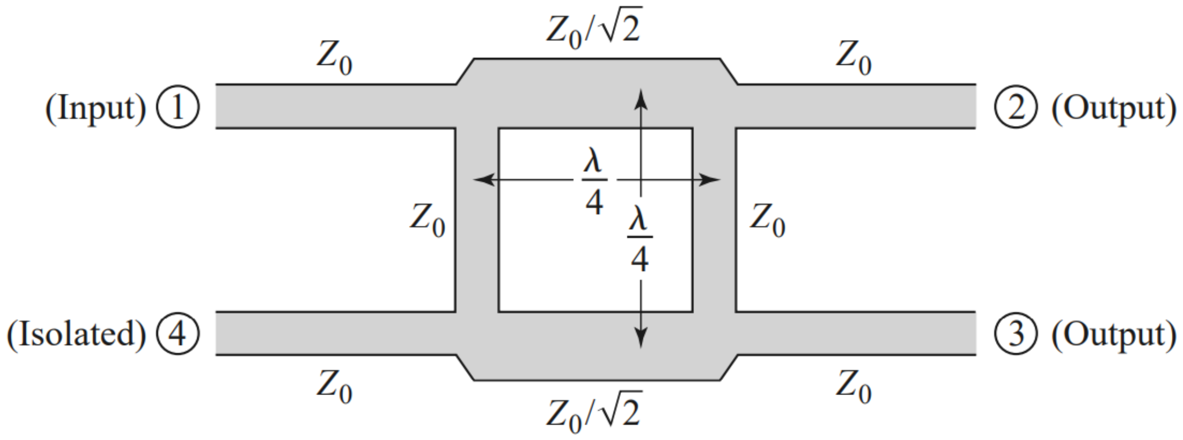
8.1 Introduction to Quadrature hybrids

- **Quadrature hybrids are $3dB$ directional couplers**
  With **90° phase difference** **in** **outputs of the through** **and** **coupled arms**.
- Applications: Microstrip lines or Stripline forms
- Also known as Branch-line hybrid



8.2 Basic operation of Quadrature hybrids

- Power entering port 1
  Even division of power between ports 2 and 3
  Phase shift between two ports: 90°



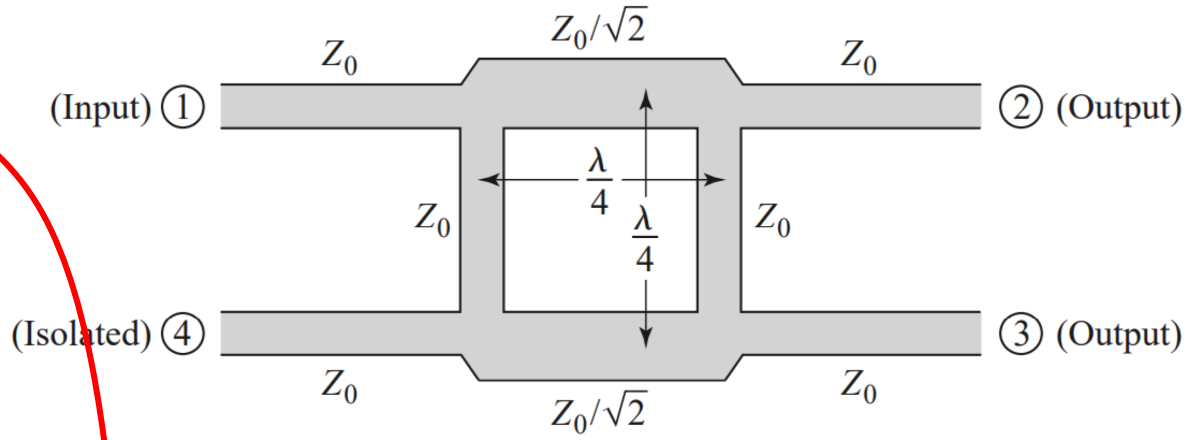
- Port 4 is isolated from port 1.
- S matrix: $[S] = \frac{-1}{\sqrt{2}}\begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$ <u>High degree of Symmetry</u>:

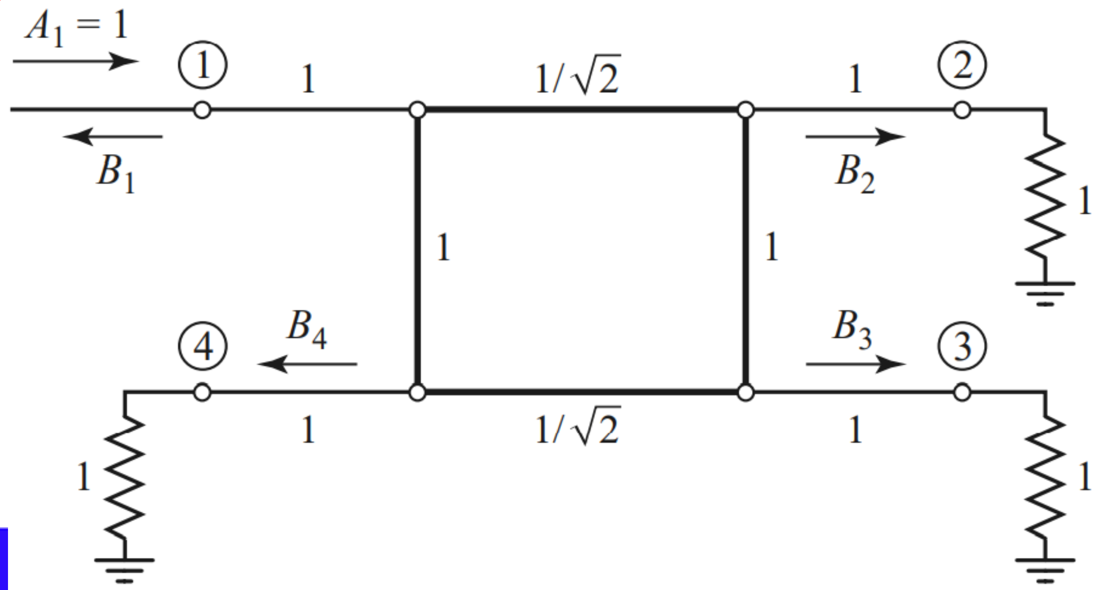
  Any port can be input,
  Isolated port will be on the same side
  Output ports on the opposite sides

- Each row – transposition of other row

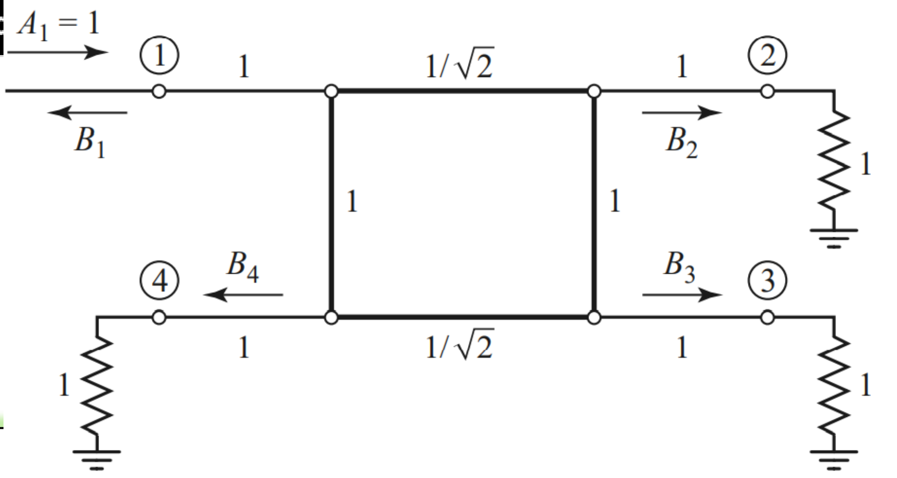
8.3 Even-Odd mode analysis

- Schematic in normalized form
- Each line : transmission line with indicated characteristic impedance normalized to Z_0
- Return ground path not indicated
- Wave of unit amplitude $A_1 = 1$ is incident at port 1
- This will be modified(decomposed) into superposition of Even and Odd mode.

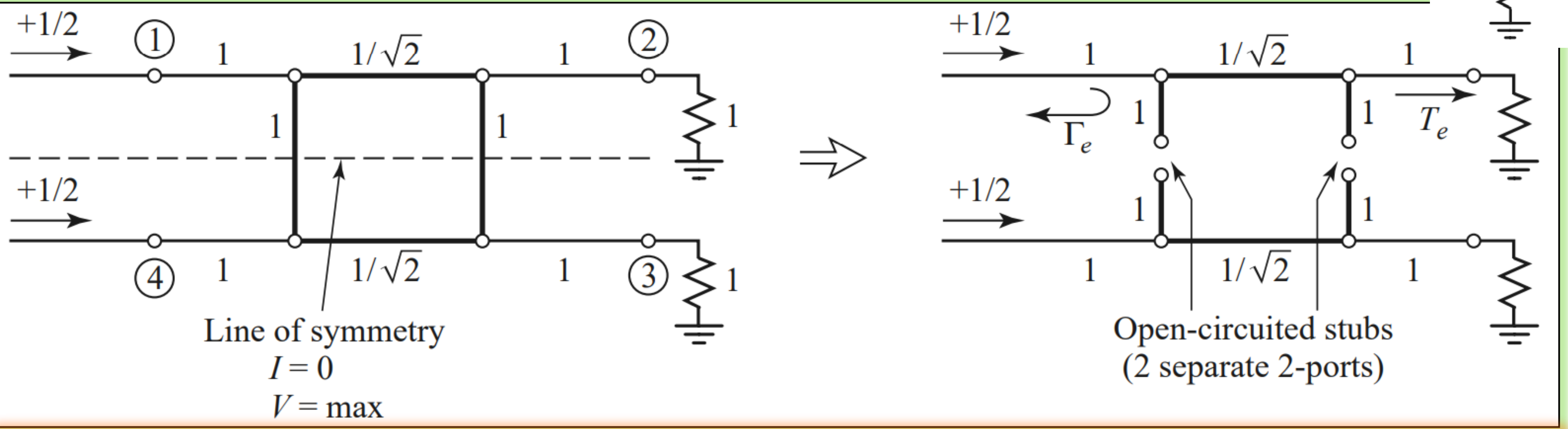




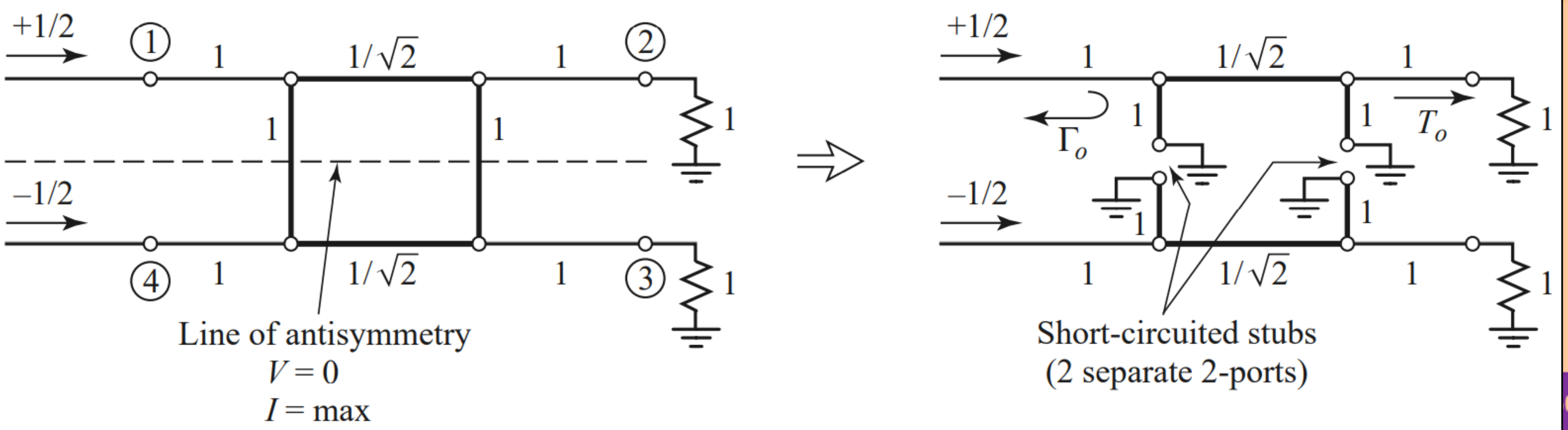
8.3 Even-Odd mode analysis



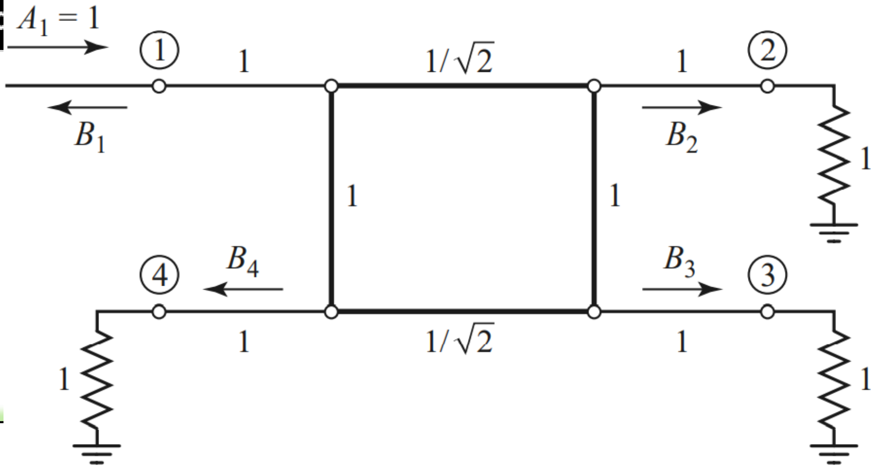
Modified(decomposed) into superposition of Even and Odd modes.



Even mode excitation

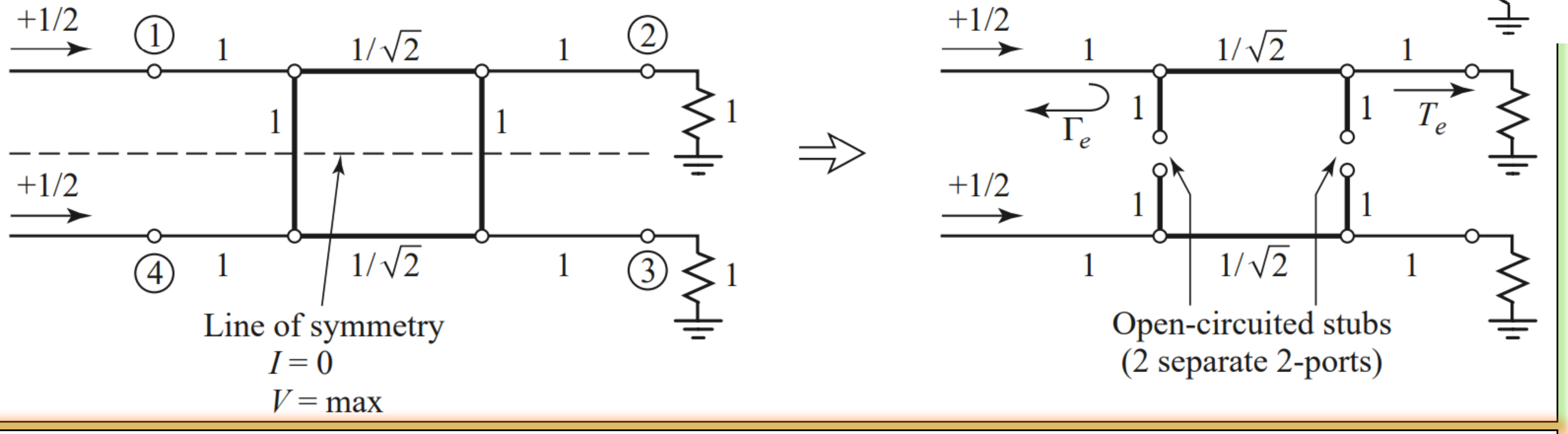


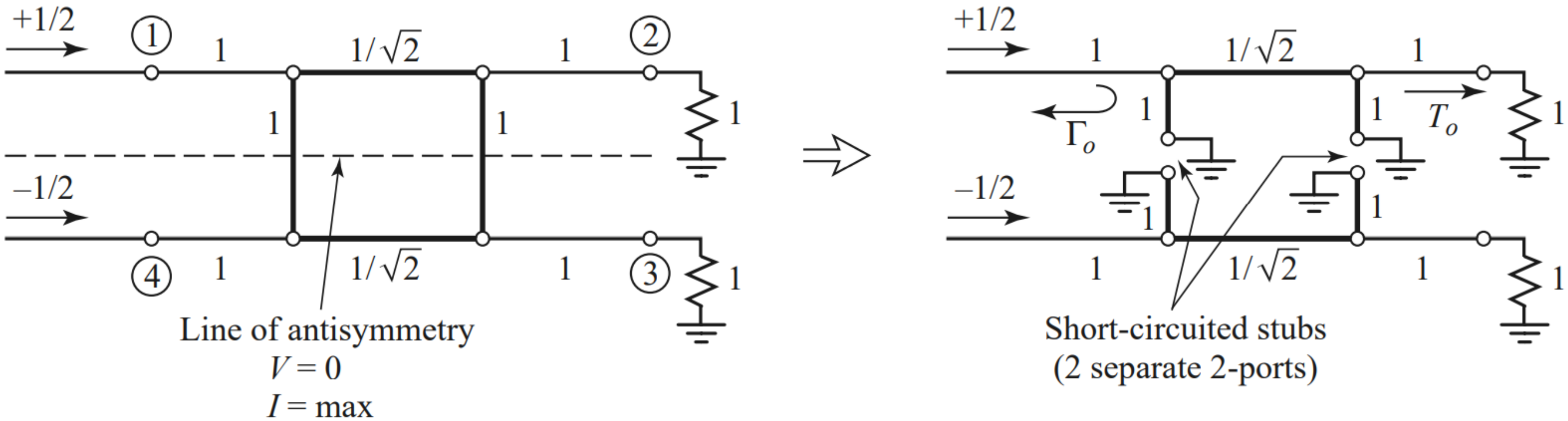
Odd mode excitation



8.3 Even-Odd mode analysis

$\Gamma_{e,o}$ and $T_{e,o}$: Even and odd mode reflection and transmission coefficients.





Emerging waves at each port

$$B_1 = \frac{1}{2}\Gamma_e + \frac{1}{2}\Gamma_0$$

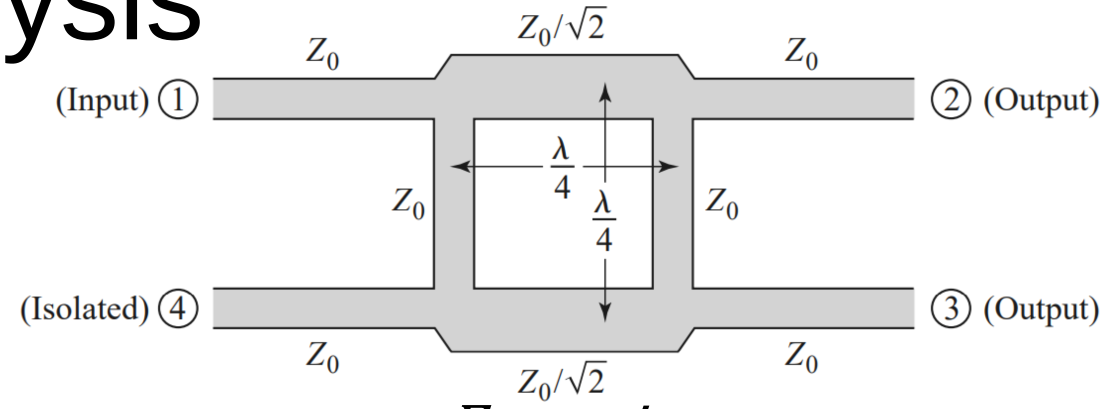
$$B_2 = \frac{1}{2}T_e + \frac{1}{2}T_0$$

$$B_3 = \frac{1}{2}T_e - \frac{1}{2}T_0$$

$$B_4 = \frac{1}{2}\Gamma_e - \frac{1}{2}\Gamma_0$$

8.3 Even-Odd mode analysis

$\Gamma_{e,o}$ and $T_{e,o}$: Even and odd mode reflection and transmission coefficients.



For $\lambda/4$ transmission line between two neighbouring ports,

$$\Gamma_e = 0, T_e = -\frac{1}{\sqrt{2}}(1+j)$$

$$\Gamma_0 = 0\ , T_0 = \frac{1}{\sqrt{2}}(1-j)$$

Emerging waves at each port

$$B_1 = \frac{1}{2}\Gamma_e + \frac{1}{2}\Gamma_0$$

$$B_2 = \frac{1}{2}T_e + \frac{1}{2}T_0$$

$$B_3 = \frac{1}{2}T_e - \frac{1}{2}T_0$$

$$B_4 = \frac{1}{2}\Gamma_e - \frac{1}{2}\Gamma_0$$

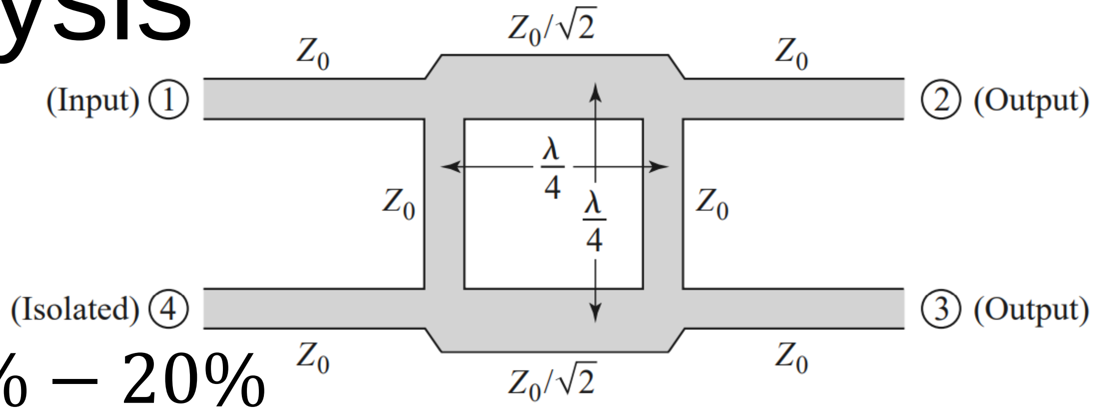
$B_1 = 0,$ Matched port 1

$B_2 = -\frac{j}{\sqrt{2}}$ (Half power -90° phase shift from port 1 to 2)

$B_3 = -\frac{1}{\sqrt{2}}$"(Half power -“180°" phase shift from port 1 to 3)"

$B_4 = 0$ (No power to port 4)

8.3 Even-Odd mode analysis



- In practice,
  Quarter-wave length requirement
  Bandwidth of branch-line is limited to $10\% - 20\%$
- Further increase can be possible by
  Multi-section matching transformers
  Multi-hole directional couplers
  Cascade of multi-sections
- Unequal power division is also possible

8.4 Problem on Quadrature Hybrid

Design a 50Ω branchline quadrature hybrid junction

- Lines are $\lambda/4$ at design frequency f_0
  Branchline impedances are : $\frac{Z_0}{\sqrt{2}} = \frac{50}{\sqrt{2}} = 35.4\Omega$