5.8 Some problems Module 5

Module:5

Course: BECE305L – Antenna and Microwave Engineering

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CHENNAI

1. Calculate the coupling factor of a directional coupler when incident power is $600mW$ and power in auxiliary waveguide is $350\mu W$.

- $P_1 = 600 \times 10^{-3} watts$ and $P_3 = 350 \times 10^{-6} watts$
- Coupling factor $C = 10 \log_{10}\left(\frac{P_1}{P_3}\right) = 32.34\text{dB}$

2. For a directional coupler, the incident power is $550mW$. Calculate the power in the main arm and auxiliary arm. The coupling factor is 30dB.

- $P_1 = 550 \times 10^{-3} watts$
- Coupling factor $C = 10 \log_{10}\left(\frac{P_1}{P_3}\right) = 30\text{dB}$

  $\frac{P_1}{P_3} = 10^{\frac{C}{10}} = 1000$ $\quad$ $P_3 = 550\mu W = 550 \times 10^{-6} watts.$
- Power in Auxiliary arm $P_3 = 550\mu W$
- Input power = Output power + Auxiliary power

  Output power= Input power- Auxiliary power= $P_1 - P_3 = 549.45mW$
- Power in main arm = Output power= $549.45mW$

3. Incident power to a directional coupler is $90W$. The directional coupler has coupling factor of $20dB$, Directivity of $35dB$ and Insertion loss of $0.5dB$. Find the output power at main arm, Coupled and Isolated arm

- $P_1 = 90W$
  $C = 20dB$ and $D = 35dB$
- $C = 10\log_{10}\left(\frac{P_1}{P_3}\right) \quad P_3 = \frac{P_1}{10^{0.1*C}}$
  $P_3 = 0.9$watts Coupled part power
- $D = 10\log_{10}\left(\frac{P_3}{P_4}\right) \quad P_4 = \frac{P_3}{10^{0.1*D}}$
  $P_4 = 284.60\mu W$
  Isolated part power $284.6\mu W$
- Received power: $\mathrm{P_r} = P_1 - (P_3 + P_4)$
  $= 89.099W$
- $P_r(dB) = 10\log\left(\frac{P_1}{P_r}\right) = 0.0436dB$
- $Insertion\ loss\ \ I = 0.5dB$
  Effective received power
  $P_{r_{effective}}(dB) = P_r(dB) - I(dB)$
  $= -0.4564dB$
  Output power at main arm:
  $-0.4564dB$

4. A magic tee is terminated at collinear ports 1 and 2 and difference port 4 by impedances of reflection coefficients ꞅ1=0.4, ꞅ2= 0.5 and ꞅ4=0.7 respectively. If 2W power is fed at sum port 3, Calculate the power reflected at port3 and power transmitted to other three ports.

If the ports were terminated with characteristic impedance

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{12} & S_{22} & S_{13} & -S_{14} \\ S_{13} & S_{13} & 0 & 0 \\ S_{14} & -S_{14} & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1/\sqrt{2} & 1/\sqrt{2} \\ 0 & 0 & 1/\sqrt{2} & -1/\sqrt{2} \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \end{bmatrix}$$

$$[b] = [S][a]$$

Towards the network, at ports,
b is reflected voltage and a is incident voltage

The ports are not terminated with characteristic impedances

4. A magic tee is terminated at collinear ports 1 and 2 and difference port 4 by impedances of reflection coefficients г1=0.4, г2= 0.5 and г4=0.7 respectively. If 2W power is fed at sum port 3, Calculate the power reflected at port3 and power transmitted to other three ports.

The ports are not terminated with characteristic impedances.

When seen towards the impedances from the ports,
$a \quad and\ b$ are inversed:

a represent reflected, b represent incident voltages

$a_1 = \Gamma_1 b_1 = 0.4\ b_1$ with Γ_1 being reflection coefficient of load

$a_2 = \Gamma_2 b_2 = 0.5\ b_2$

$a_4 = \Gamma_4 b_4 = 0.7\ b_4$

$|a_3|^2 = 2\text{W} \quad a_3 = \sqrt{2} = 1.414$

Substituting the values in S matrix for the network with b as reflected, and a as incident signals,

$$[b] = [S][a]$$

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Substituting the values in S matrix

$$[b] = [S][a] \qquad \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1/\sqrt{2} & 1/\sqrt{2} \\ 0 & 0 & 1/\sqrt{2} & -1/\sqrt{2} \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \end{bmatrix} \begin{bmatrix} 0.4b_1 \\ 0.5\, b_2 \\ 1.414 \\ 0.7b_4 \end{bmatrix}$$

$$b_1 = \frac{1.414}{\sqrt{2}} + \frac{0.7b_4}{\sqrt{2}} = 1 + 0.495b_4$$

$$b_2 = \frac{1.414}{\sqrt{2}} - \frac{0.7}{\sqrt{2}}b_4 = 1 - 0.495b_4$$

$$b_3 = 0.4\frac{b_1}{\sqrt{2}} + \frac{0.5}{\sqrt{2}}b_2 = 0.283b_1 + 0.354\, b_2$$

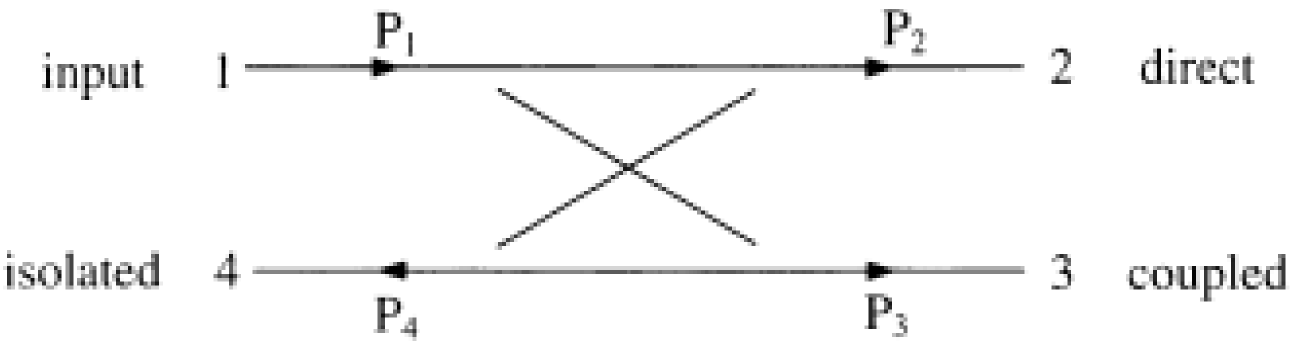
$$b_4 = 0.4\frac{b_1}{\sqrt{2}} - \frac{0.5}{\sqrt{2}}b_2 = 0.283b_1 - 0.354\, b_2$$

On solving first, second and fourth equations (dependent on b_1, b_2, b_4)

$b_1 = 0.95, b_2 = 1.05, b_4 = -0.104, b_3 = 0.64$

$P_1 = |b_1|^2 = 0.9025$ W, $P_2 = |b_2|^2 = 1.1$ W , $P_3 = |b_3|^2 = 0.41W$, $P_4 = |b_4|^2 = 0.011W$

5. A 6-dB branch line coupler as shown in Fig.1 has a directivity of 43 dB. If the input power P_1= 20 mW, what are the power outputs at ports 2, 3 and 4? Assume that the coupler (a) is lossless and (b) has an insertion of 0.4 dB.



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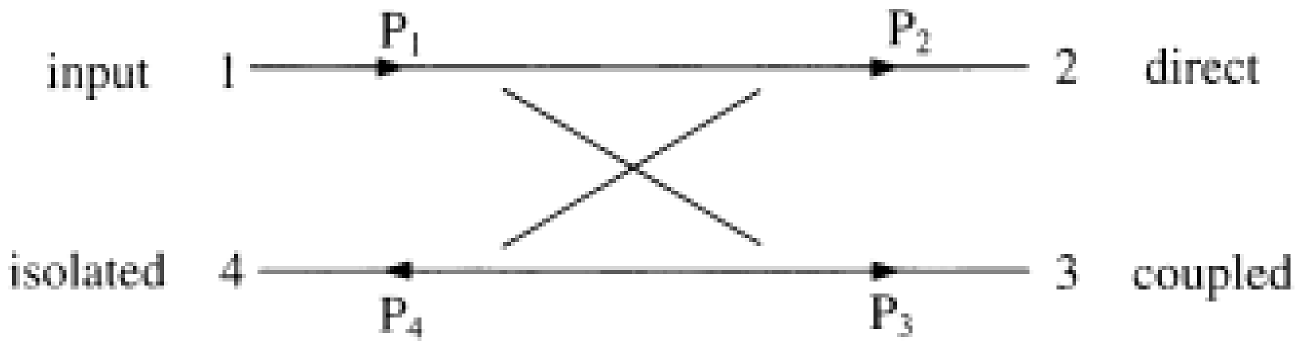

For lossless cases:

- Coupling factor $C = 10\log_{10}\left(\frac{P_1}{P_3}\right)$
  $= 6\text{dB}$
- $\frac{P_1}{P_3} = 10^{0.1C} = 10^{0.6} = 3.98$ $P_3 = \frac{20mW}{3.98} = 5.025\, mW$
- Directivity $D = 10\log_{10}\left(\frac{P_3}{P_4}\right)$ $P_4 = \frac{P_3}{10^{0.1*D}} = \frac{5.025mW}{10^{0.1*43}} = 0.25\,\mu W$
- Received power: $\mathrm{P_r} = P_1 - (P_3 + P_4) = 14.975\, mW$
- $P_r(dB) = 10\log\left(\frac{P_1}{P_r}\right) = 0.1256\, dB$

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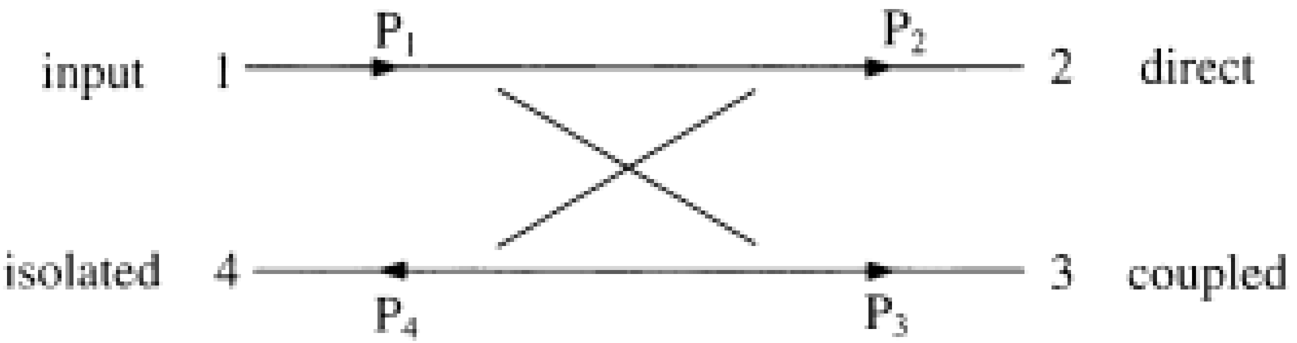

- $P_r(dB) = 10\log\left(\frac{P_1}{P_r}\right) = 0.1256\ dB$
- **<u>For lossy case</u>**:
- $Insertion\ loss\ \ I = 0.4dB$

  Effective received power

  $$P_{r_{effective}}(dB) = P_r(dB) - I(dB)$$

  $$= -0.274dB$$