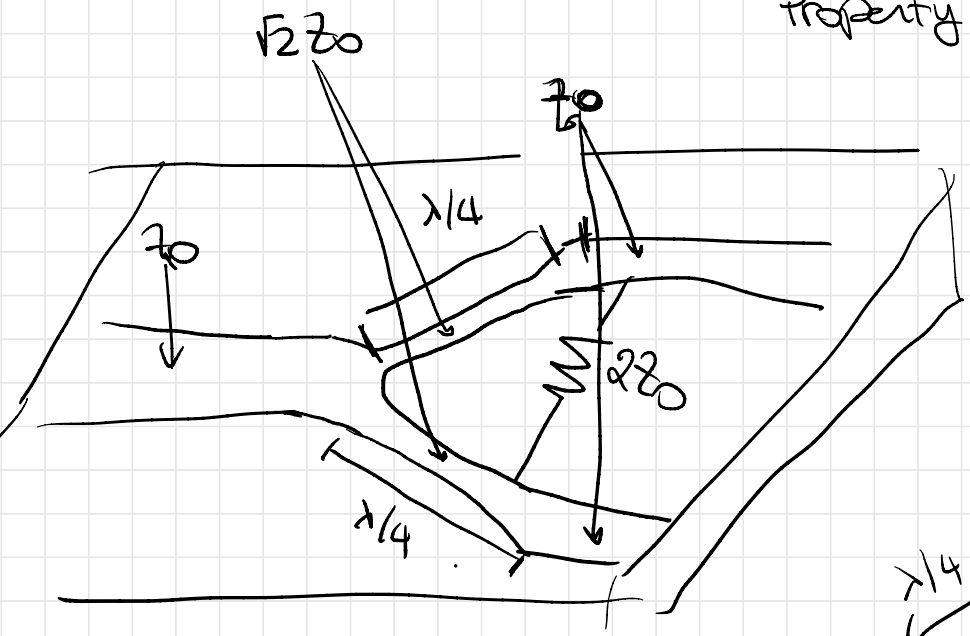
MICROWAVE ENGINEERING

Lecture 25:
Dividers and
couplers –
second part

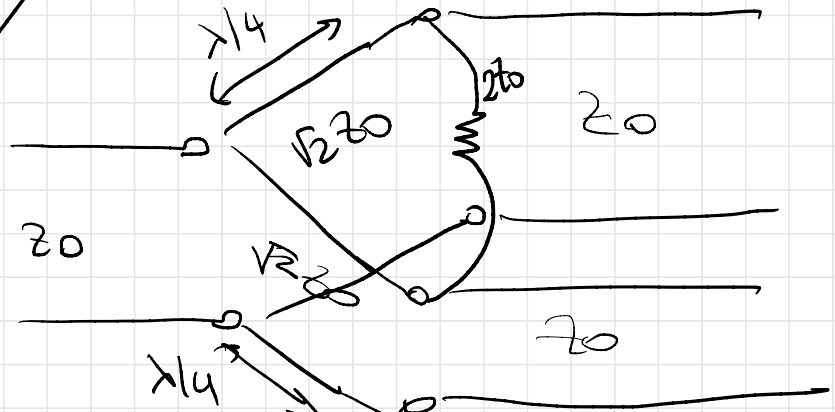
WILKINSON POWER DIVIDER



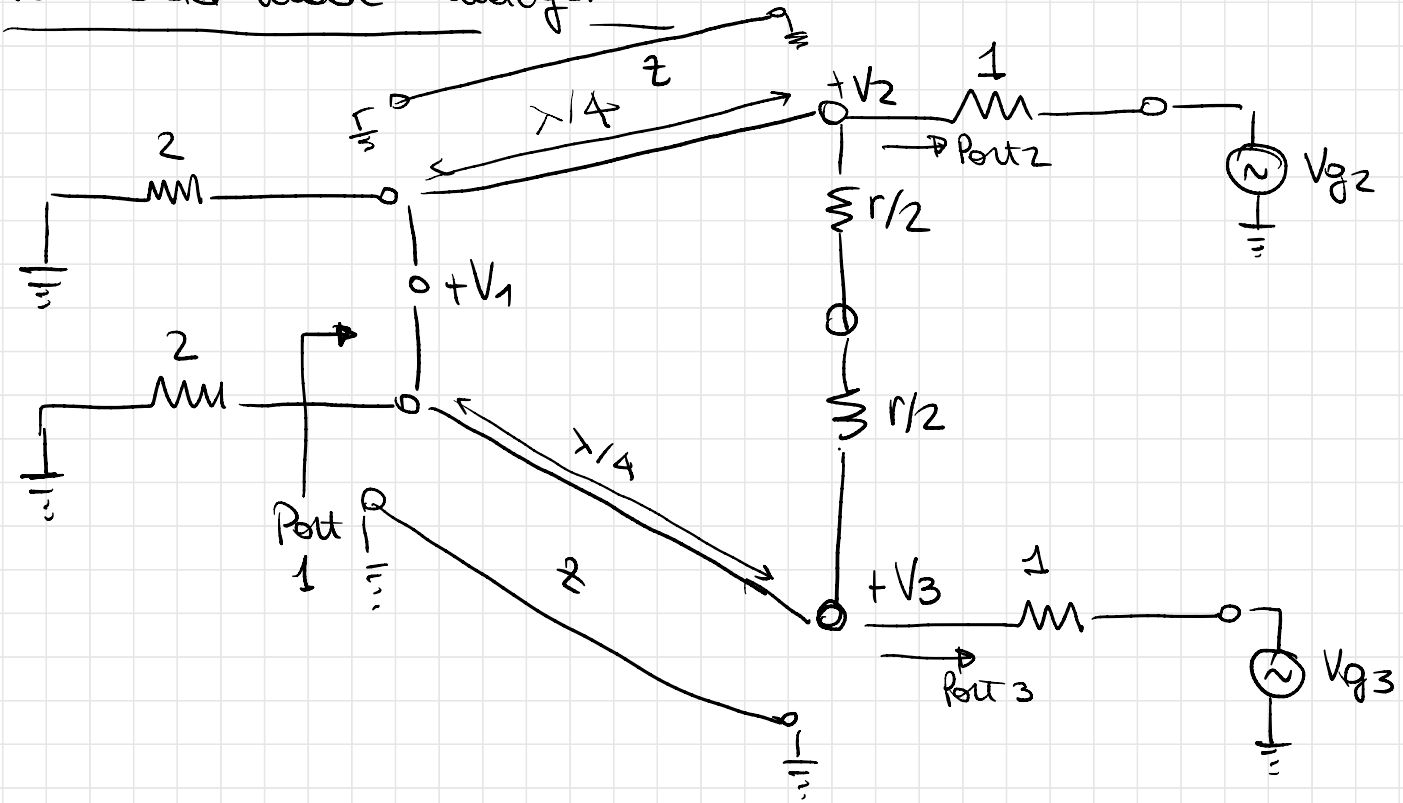
3 PORTS RESISTIVE POWER DIVIDER

Property :- ISOLATION in between the output ports.

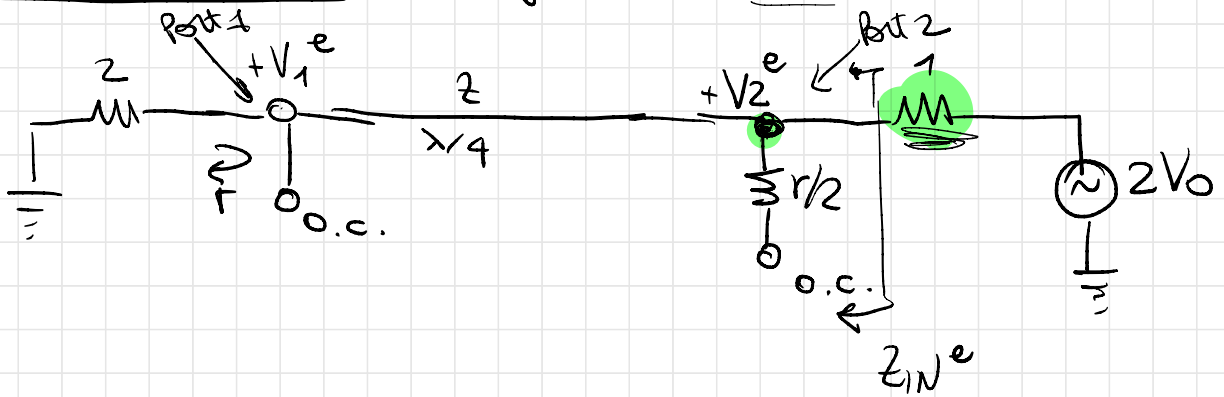
- LOSSLESS when the output ports are matched



Even-odd mode analysis



EVEN MODE ANALYSIS $V_{g2} = V_{g3} = 2V_0 \Rightarrow V_2^e = V_3^e$



$$z_{in}^e = \frac{z^2}{2}$$

If $z = \sqrt{2} \rightarrow Z_{IN}^e = 1 \Rightarrow$ PORT 2 will be matched for even mode

Then $\boxed{V_2^e = V_0} \rightarrow Z_{IN} // 1 \rightarrow Z_{eq} = 0.5$

V_1^e can be found from π equations with $Z_L = 0$ at port 1 and

$x = -\frac{\lambda}{4}$ at port 2

$$V(x) = V^+ \left(e^{-j\beta x} + \Gamma e^{j\beta x} \right)$$

$$\Downarrow$$

$$e^{-j\frac{2\pi}{\lambda}\left(-\frac{\lambda}{4}\right)} = e^{j\frac{\pi}{2}} = j$$

$$e^{j\frac{2\pi}{\lambda}\left(-\frac{\lambda}{4}\right)} = e^{-j\frac{\pi}{2}} = -j$$

① $V_2^e = V\left(-\frac{\lambda}{4}\right) = jV^+(1-\Gamma) = V_0$

② $V_1^e = V(0) = V^+(1+\Gamma)$

$$V^+ = \frac{V_0}{j(1-\Gamma)}$$

$$V_1^e = \frac{V_0}{j}\,\frac{1+\Gamma}{1-\Gamma} = jV_0\,\frac{1+\Gamma}{\Gamma-1}$$

$$\Gamma = \frac{2-\sqrt{2}}{2+\sqrt{2}}$$

(porta 1)

$$V_1^e = jV_0 \frac{1+\Gamma}{\Gamma-1} = jV_0 \left[\frac{1 + \frac{2-\sqrt{2}}{2+\sqrt{2}}}{\frac{2-\sqrt{2}}{2+\sqrt{2}} - 1} \right] =$$

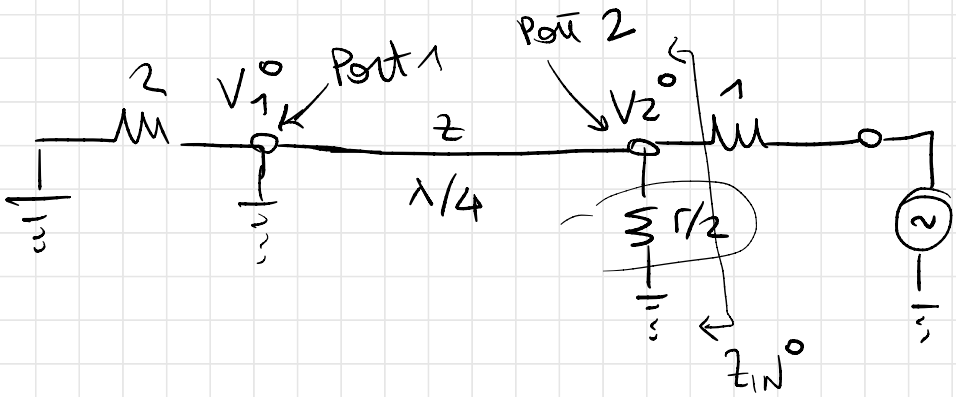
$$= jV_0 \left[\frac{2+\cancel{\sqrt{2}}+2-\cancel{\sqrt{2}}}{\cancel{2}-\sqrt{2}-\cancel{2}-\sqrt{2}} \right] = jV_0 \left[\frac{4}{-2\sqrt{2}} \right] = -jV_0\sqrt{2}$$

ODD MODE ANALYSIS

$$V_{g2} = -V_{g3} = 2V_0$$

$$\Downarrow$$

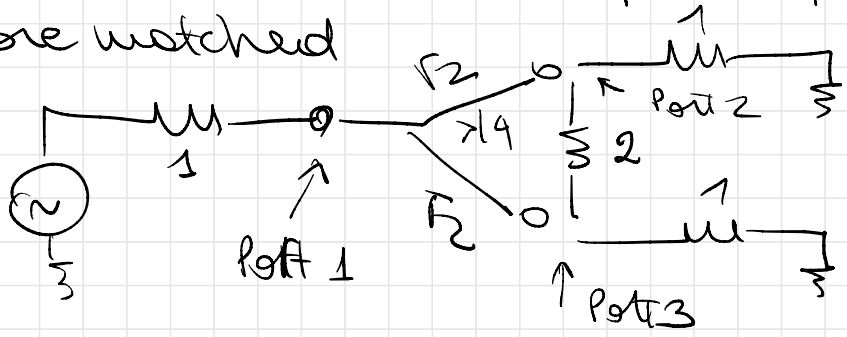
$$V_2^o = -V_3^o$$



In port 2 we see $r/2$ and a $\lambda/4$ TL connected in // and shortened at port 1. The $\lambda/4$ line will look as an O.C. at port 2. Port 2 will be matched if $r = 2$.

It follows $V_2^o = V_0$ and $V_1^o = 0$ ⇒ All power ends in the resistor

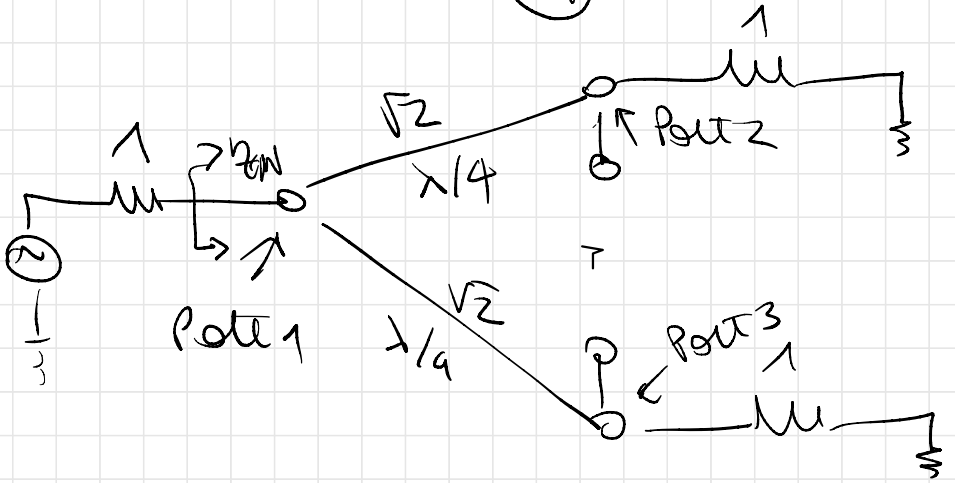
Finally we have to find the input impedance when ports 2 and 3 are matched



$V_2 = V_3$ en la the even mode excitation

⇓

No current is flowing in the resistor



The input imp.

$$\underline{Z_{IN}} = \frac{1}{2}\left(\sqrt{2}\right)^2 = 1$$

The S parameters for the Wilkinson power divider are

$S_{11} = 0$ ($Z_{IN} = 1$ at port 1)

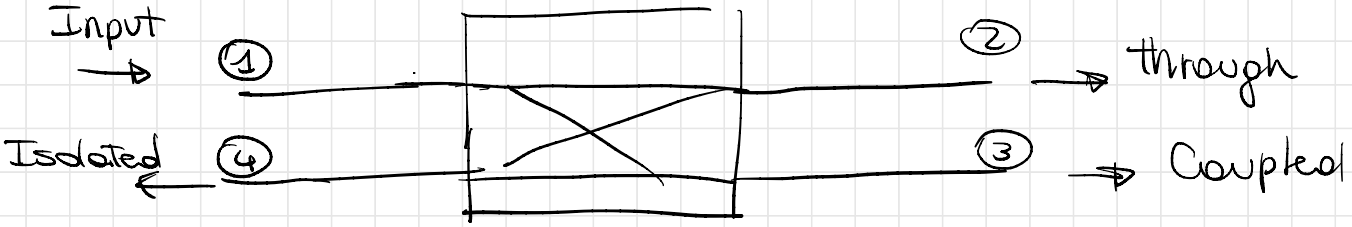
$S_{22} = S_{33} = 0$ (ports 2 and 3 are matched)

$$S_{12} = S_{21} = \frac{V_1^e + V_1^o}{V_2^e + V_2^o} = -j\sqrt{2}$$

$S_{13} = S_{31} = -j\sqrt{2}$ $\qquad$ $S_{23} = S_{32} = 0$ (Port 2 and 3 are isolated)

NOTE: THE DIVIDER IS LOSSLESS ONLY IF PORTS 2 and 3 ARE MATCHED

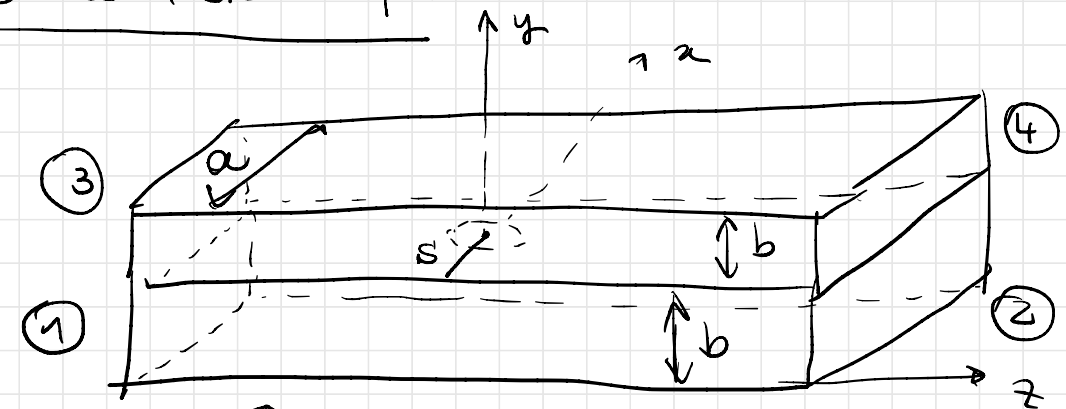
DIRECTIONAL COUPLERS



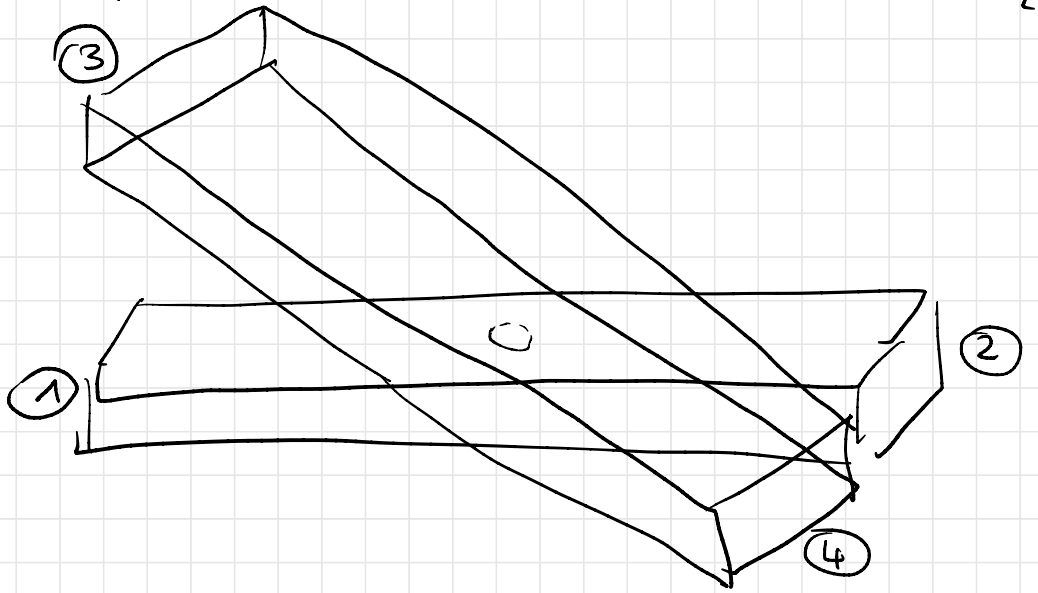
Coupling C Isolation I $D = I - C$

Directivity D

- Bethe Hole Coupler



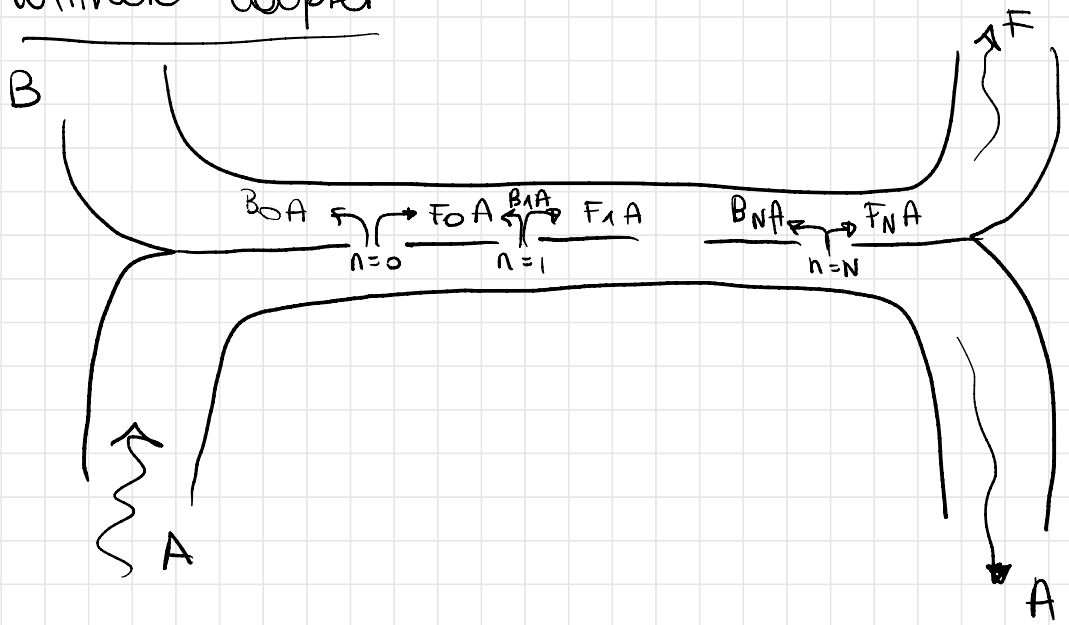
PARALLEL WAVEGUIDES



SKEWED WAVEGUIDES

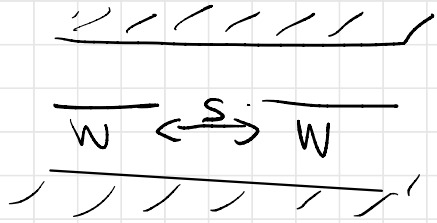
Cons:
- Narrow bandwidth
- Difficult fab in the skewed conf.

- Multihole coupler

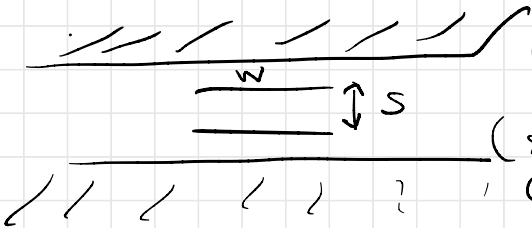


N+1 hole waveguide directional coupler

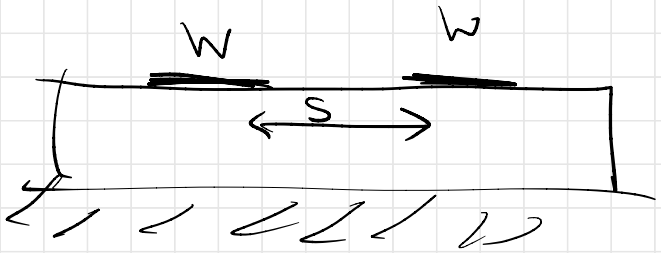
- Coupled line directional coupler



COUPLED STRIPLINE (planar or edge coupled)

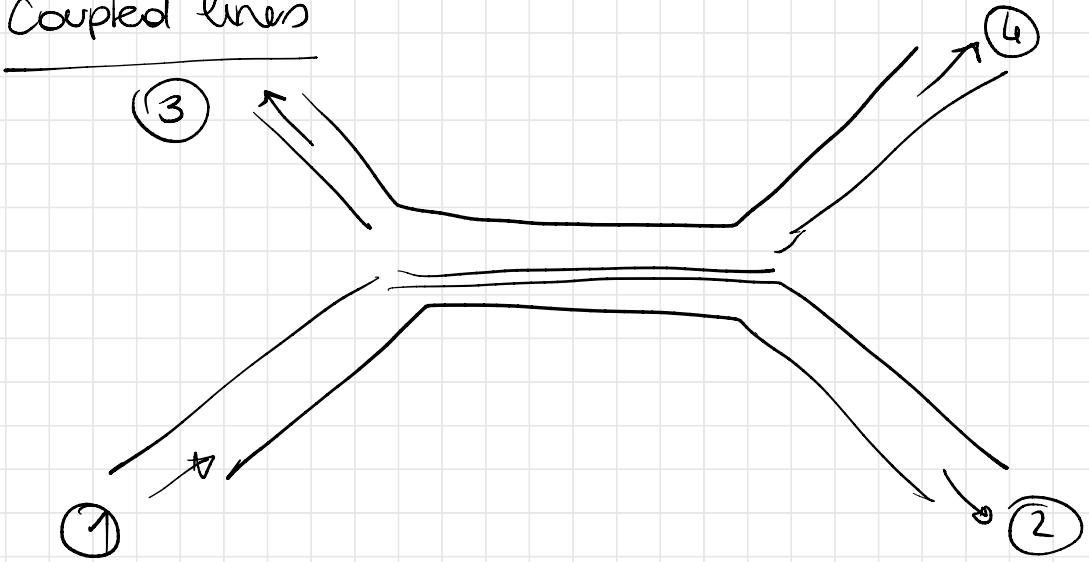


COUPLED STRIPLINES (stacked coupling)

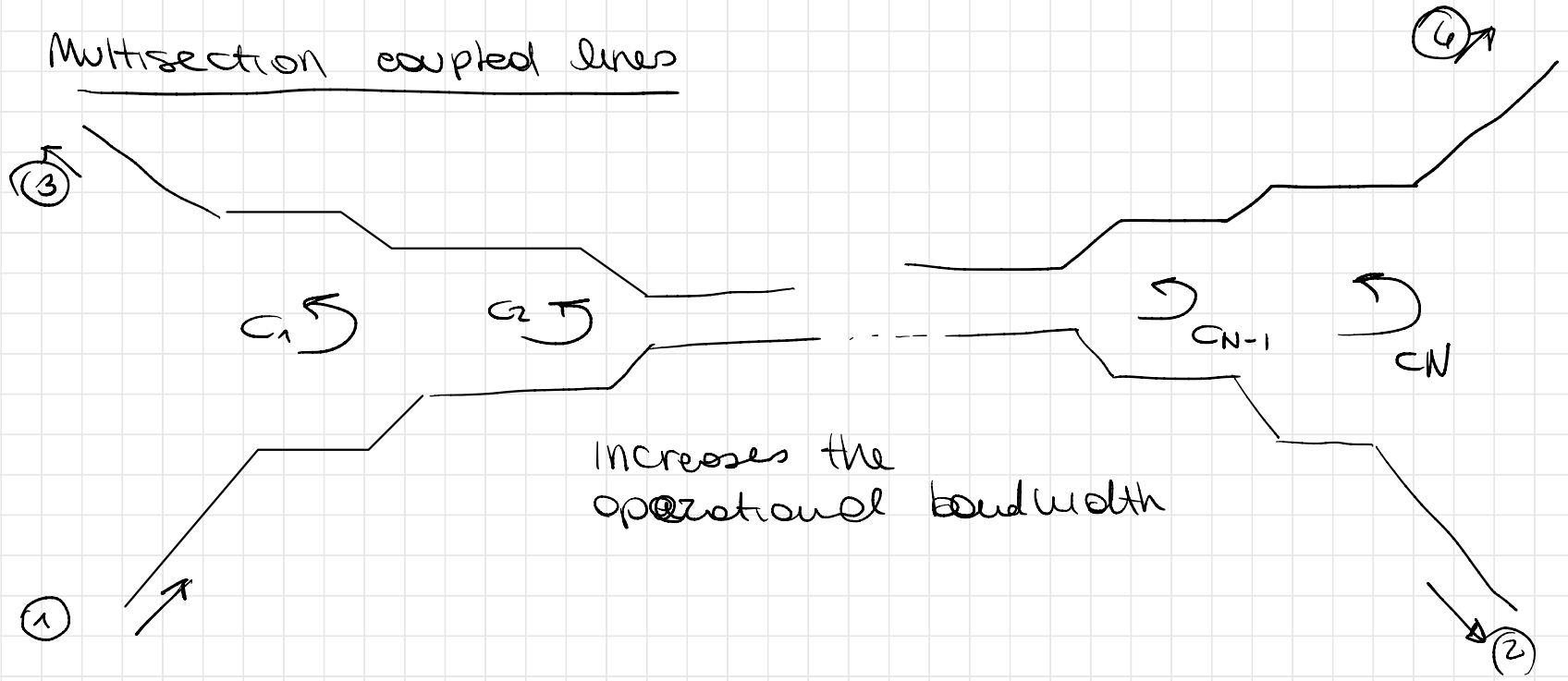


COUPLED MICROSTRIPS

Coupled lines

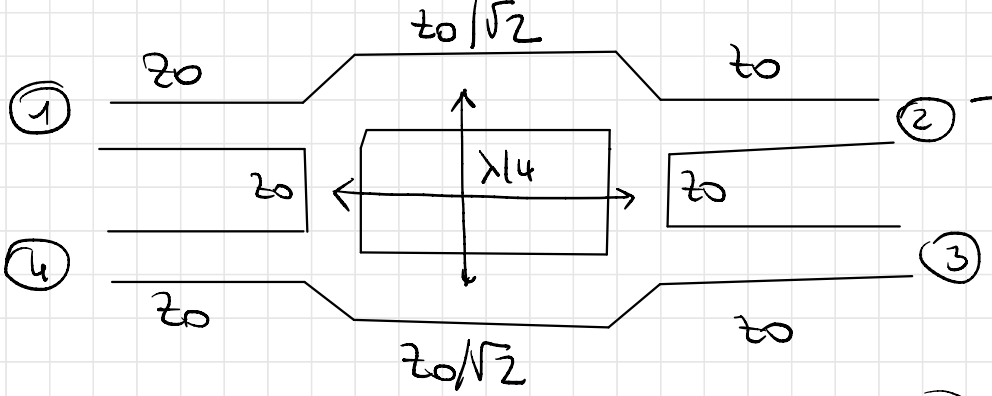


Multisection coupled lines



Increases the operational bandwidth

The quadrature (90°) hybrid



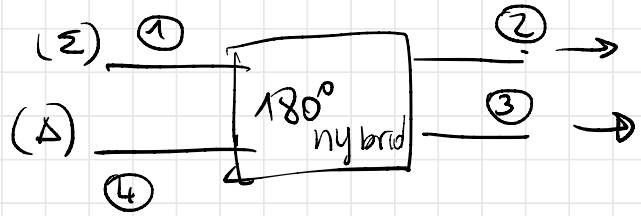
Branch line coupler

Any port can be the input port

$$[S] = -\frac{1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$$

The 180° HYBRID

4 ports network → 180° between port 2 and ③



Port 1 input → in phase ② and ③

Port 4 input → 180° phase shift ② and ③

COMBINER : inputs at ports 2 and 3 → Port 1 Σ combine

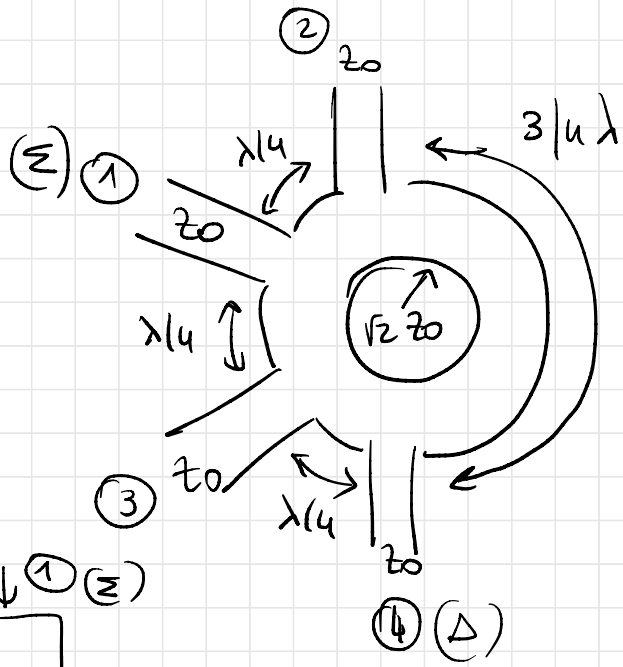
→ Port 4 Δ difference

$$[S] = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{bmatrix}$$

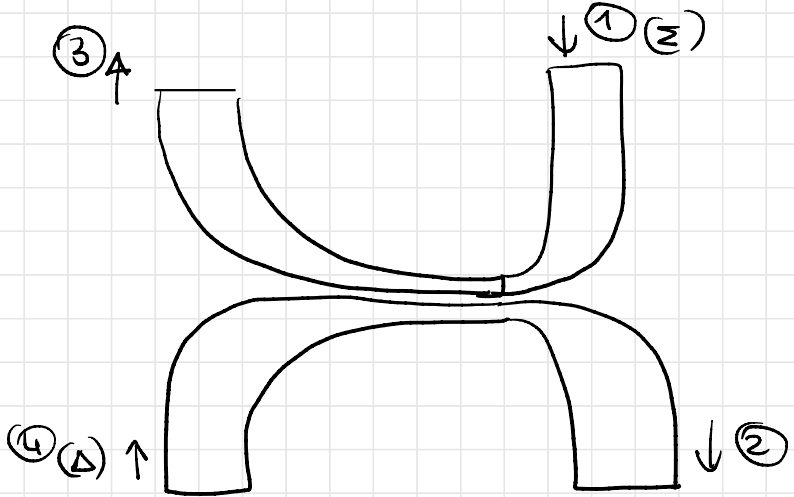
Realization:

RING HYBRID or RAT RACE

(microstrip/ stripline) →



Tapered coupled lines



Waveguide hybrid junction (T-MAGIC)