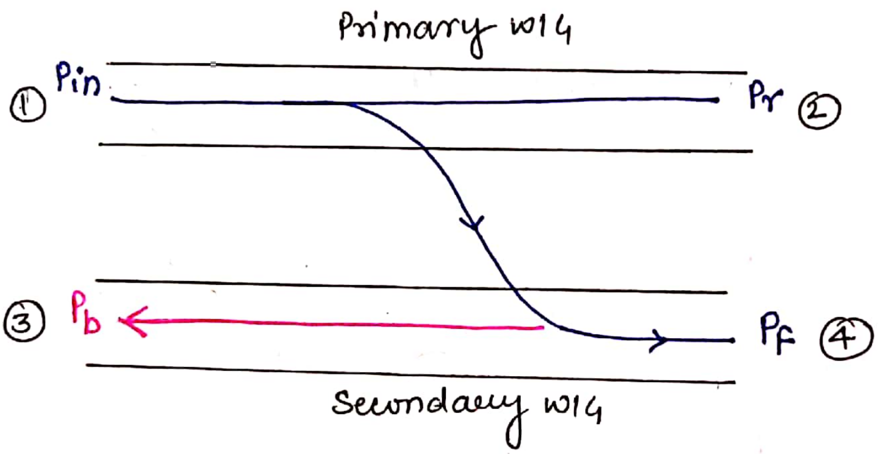
SUBJECT: Microwave and Radar Engineering

Directional coupler: A directional coupler is a four port waveguide Junction. It consist of primary waveguide (port 1-2) and secondary waveguide (port 3-4). When all ports are terminated in their characteristic impedences, there is free transmission of power, without reflection, between Port 1 and 2. There is no transmission of power between port 1 and port 3 or port 2 and port 4, because no coupling exist between these two pair of ports.

- Directional coupler uses the distributive properties of microwave circuit.



Pin: Input Power
Pf: Forward Power
Pr: Received Power
Pb: Back Power (unwanted Power)

* ideally $P_b = 0$

- We gave input Power from Port ①, which is received at PORT ②, a fraction of input power coupled to port ④. so P_i, P_r and P_f all are desired but P_b is not desired/unwanted. Practically, $P_b \neq 0$

- **Figure of Merit of directional coupler**:-

① coupling factor: What amount of input power (Pin), given to Port ③.

$$C = 10\log \frac{P_i}{P_f}$$

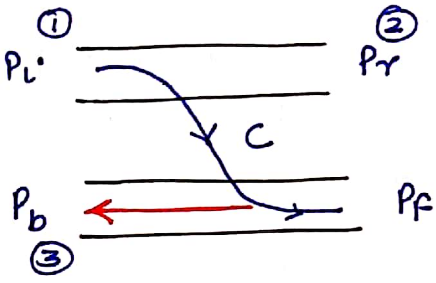
normally, C = 20dB, so,

$$20 = 10\log\frac{P_i}{P_F} \Rightarrow \log\frac{P_i}{P_F} = 2, \quad \frac{P_i}{P_F} = 10^2 = 100$$

$$\therefore \boxed{P_F = \frac{P_i}{100}}$$

<u>means,</u> $\frac{P_i}{100}$ part of input power we couple (feed) to port 4.

② <u>Directivity</u> → Pin was input power, and we couple a part of input power to port ④ as forward Power. (which is wanted but some power of P_F flow back to port ③ as back power, (which is unwanted).



Now, directivity is relation between P_F and P_b.

Directivity, $\boxed{D = 10\log\frac{P_F}{P_b}}$

ideally, $P_b = 0$

$\therefore \boxed{D = \infty}$

Practically, <u>$D = 60dB$</u>,

$$\therefore \quad 60 = 10\log\frac{P_F}{P_b} \rightarrow \log\frac{P_F}{P_b} = 6, \quad \frac{P_F}{P_b} = 10^6$$

$\therefore \boxed{P_b = P_F/10^6}$ So, we conclude $\boxed{P_b << P_F}$

③ <u>Isolation Factor:</u> In a directional coupler Port ① and Port ③ must be perfectly isolated. So isolation factor defines a relation between Input Power (Pin) and Back power (P_b).

$$\boxed{I = 10\log\frac{P_i}{P_b}}$$

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ideally, $P_b = 0$, so, Isolation Factor, $\boxed{I = \infty}$

Now,
$$I = 10\log \frac{P_i}{P_b}$$
$$= 10\log \frac{P_i}{P_f} \times \frac{P_f}{P_b} = \underbrace{10\log \frac{P_i}{P_f}}_{C} + \underbrace{10\log P_f/P_b}_{D}$$

$\therefore$ $\boxed{I = C + D}$ — this is relation b/w isolation factor, coupling factor and directivity.

- For ideal directional coupler, port ① and port ③ are isolated and port ②, port ④ are isolated.

so,
$$S_{13} = S_{31} = 0$$
$$S_{42} = S_{14} = 0$$

- In a directional coupler all four ports are perfectly matched. thus diagonal element of S matrix should be zero.

$\because$ In directional coupler there are 4 ports,

so, $S_{11} = S_{22} = S_{33} = S_{44} = 0$

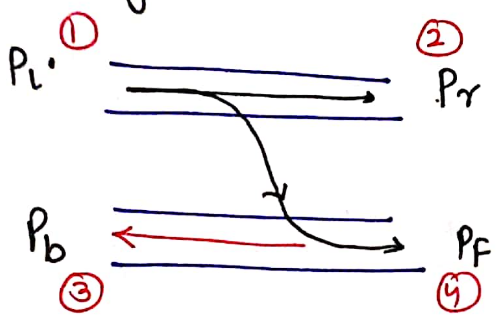
S-matrix of directional coupler -

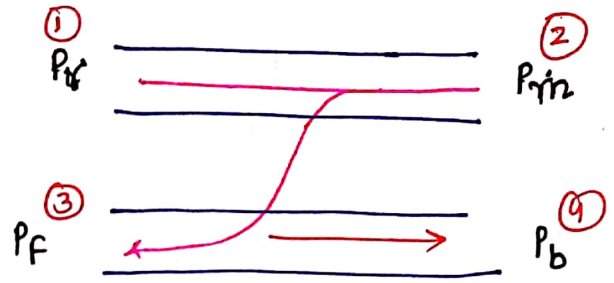
$$S = \begin{bmatrix} 0 & S_{12} & 0 & S_{14} \\ S_{21} & 0 & S_{23} & 0 \\ 0 & S_{32} & 0 & S_{34} \\ S_{41} & 0 & S_{43} & 0 \end{bmatrix}_{4\times4}$$

using property of S-matrix, S matrix of directional coupler reduced to -

$$S = \begin{bmatrix} 0 & P & 0 & jq \\ P & 0 & jq & 0 \\ 0 & jq & 0 & P \\ jq & 0 & P & 0 \end{bmatrix}_{4\times4}$$

Symmetrical directional coupler:

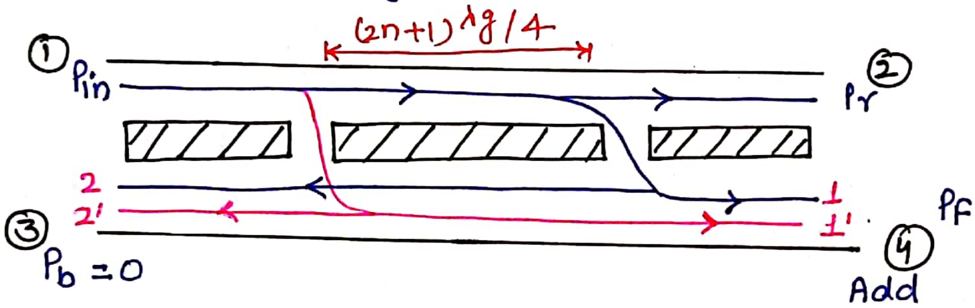




Here, both are same.

Two hole directional coupler:

Several type of directional coupler exist, such as two-hole directional coupler, four hole directional coupler etc. Most commonly used is two hole directional coupler.



→ Gap between two holes should be odd multiple of $\lambda g/4$ so, that the power at port ④ get added and power (2, 2') at port ③ will cancel out each other.

$$\therefore \boxed{l = (2n+1)\lambda g/4}$$

here, $n = 0, 1, 2, 3, \ldots$

λg: Guided wavelength.