DIRECTIONAL COUPLERS

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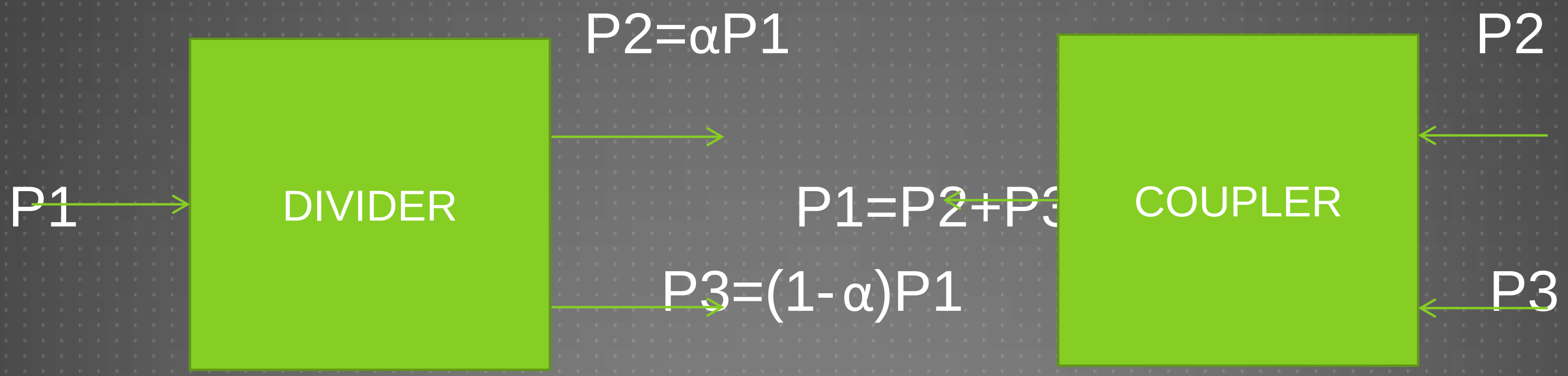
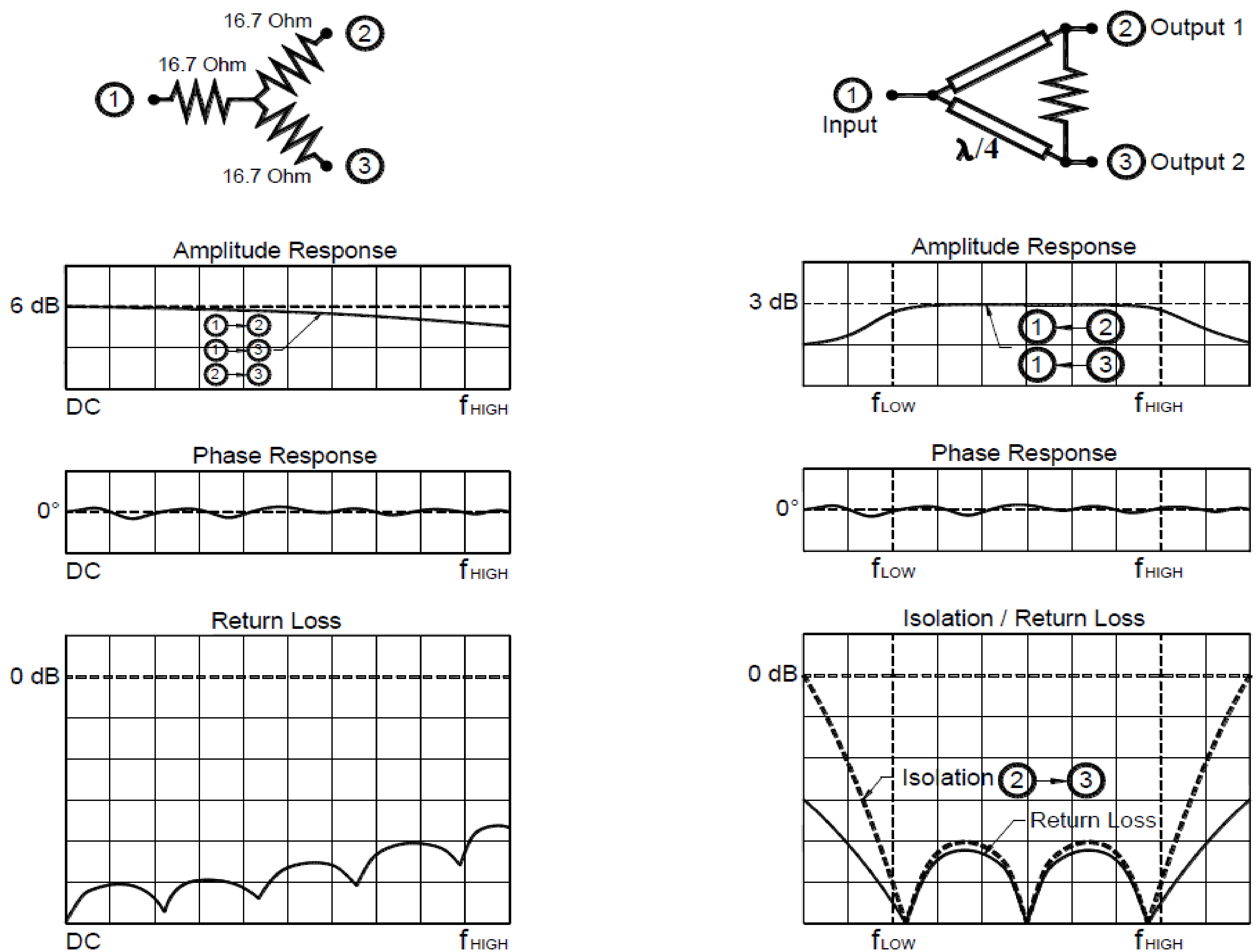
POWER DIVISION AND POWER COMBINING



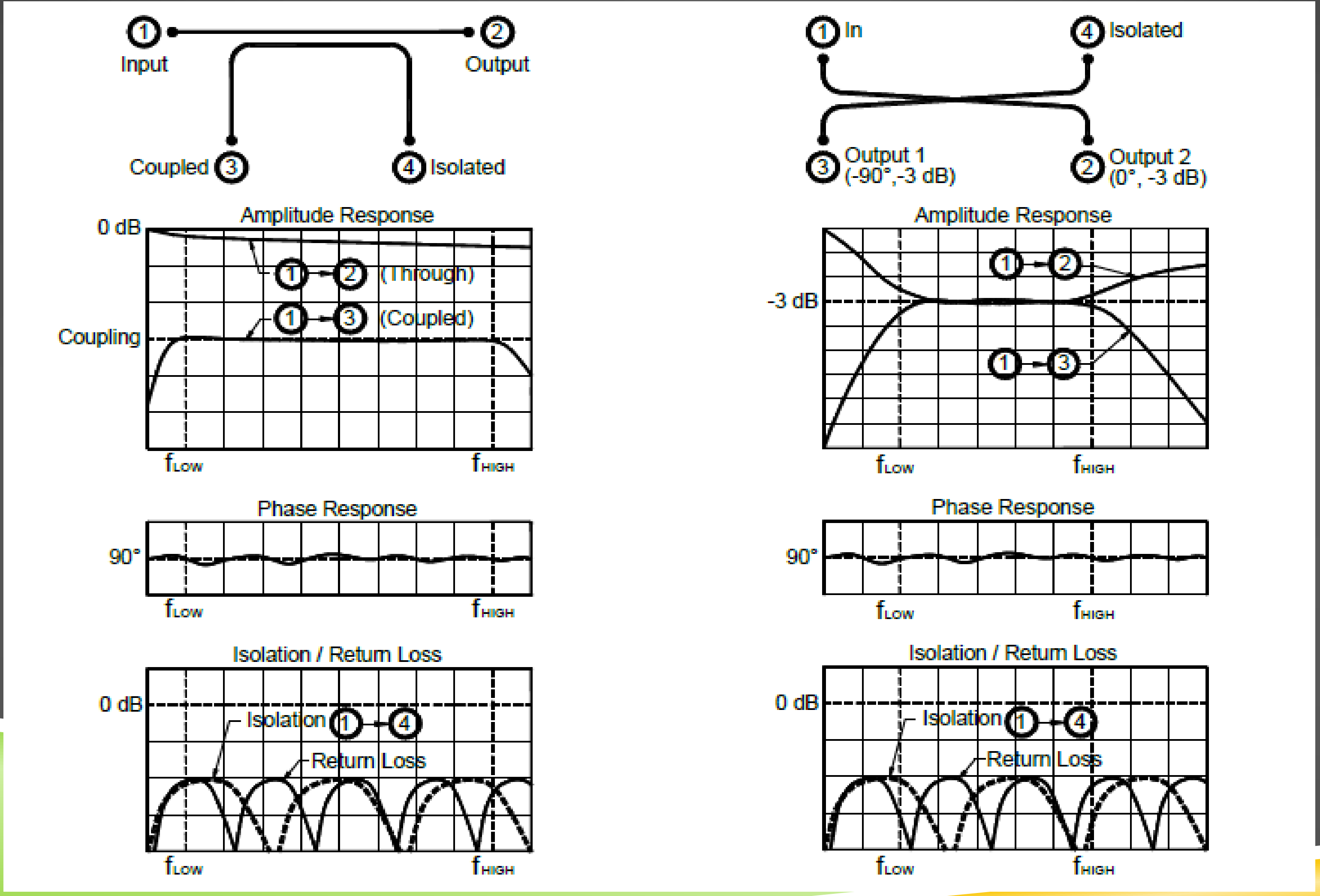
POWER DIVIDERS AND COUPLERS

- Passive microwave components
- Used in Power division and Power combining
- 3 port or 4 port components
- T-junctions
- Hybrids and directional couplers
- Quadrature and Magic-T junctions
- Resistive power dividers
- Wilkinson power dividers

WILKINSON AND RESISTIVE POWER DIVIDERS



DIRECTIONAL COUPLER AND QUADRATURE HYBRID COUPLER



DIRECTIONAL COUPLERS

- Passive device that divided and distributes power.
- Couples part of the transmission power by a known amount out through another port
- Uses two transmission lines set close enough together such that energy passing through one is coupled to the other.

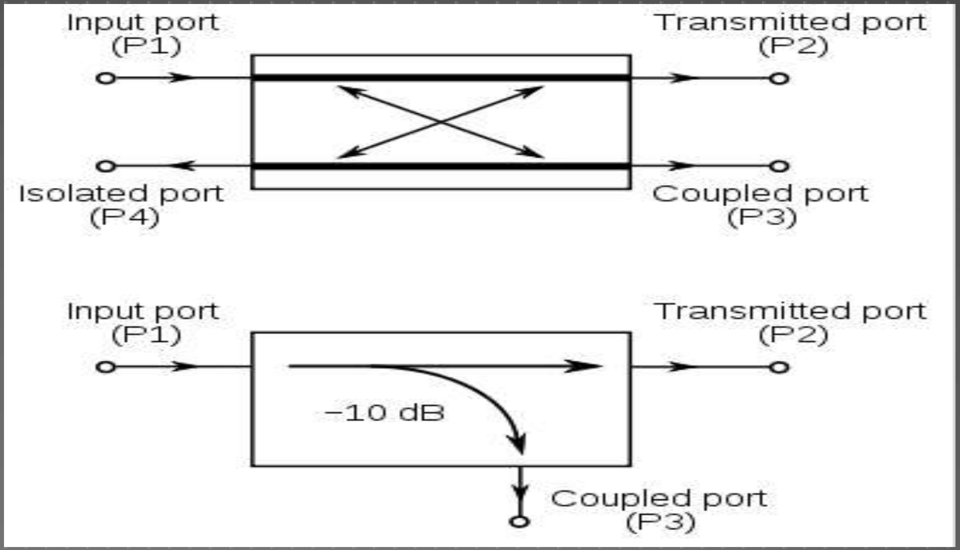
- The device has four ports:

Input, Port

Through Port

Coupled, Port

Isolated Port



- The term "main line" refers to the section between ports 1 and 2.
- Ports 1&2 are Primary ports
- Ports 3&4 are Secondary ports

DIFFERENCES

- COUPLERS and DIVIDERS:

Phase shift

- DIRECTIONAL COUPLERS and QUADRATURE HYBRIDS:

Power splitting

- Limiting frequencies

REQUIREMENTS:

- Matched
- Lossless
- Reciprocal

IDEAL DIRECTIONAL COUPLER:

No power delivered to PORT4

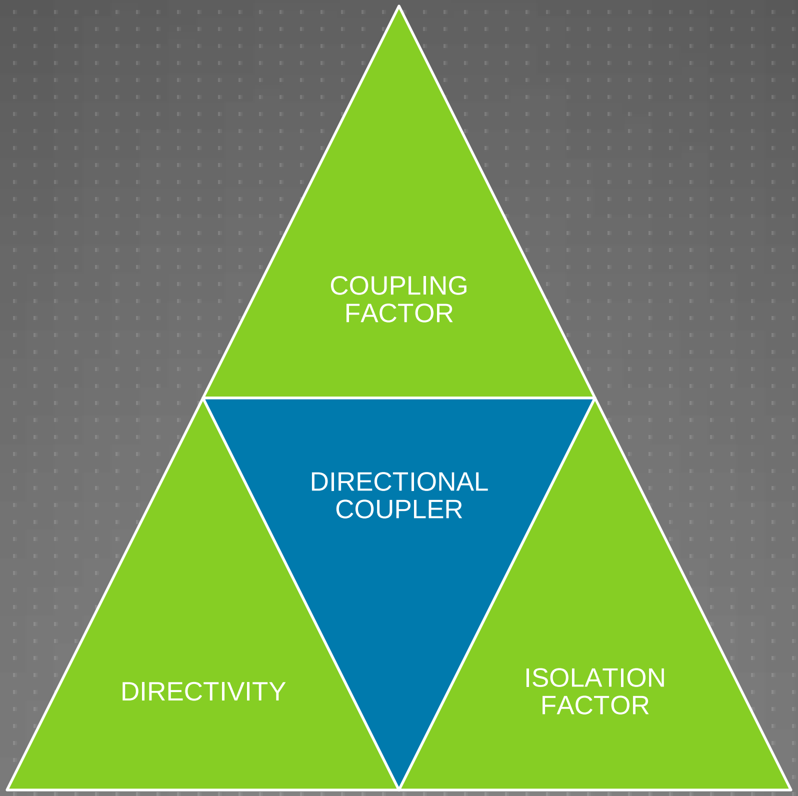
FORWARD COUPLING:

- Energy that propagates down transmission line starts a parallel wave down transmission line 2 .
- Most common forward coupler is the multi-hole coupler realized in waveguide.
- In this case the holes are spaced a quarter wave apart so that the reverse wave cancels out.
- Asymmetric multi-section coupled structures provide forward-wave, in-phase response.

BACKWARD COUPLING:

- *Reverse* coupler
- Energy that propagates down transmission line starts a reverse wave down transmission line 2.
- Single-section coupled transmission lines are always backward-wave couplers (and outputs are in quadrature),
- Eg: Lange coupler
- Symmetric multi-section couplers provide backward-wave, quadrature response.

FIGURES OF MERIT:



COUPLING FACTOR:

- Indicates the fraction of input power that is coupled to the output port.

$$C_{3,1} = -10\log\left(\frac{P_3}{P_1}\right) \quad \text{dB}$$

where P_1 is the input power at port 1 and P_3 is the output power from the coupled port.

- Coupling is not constant, but varies with frequency.
- Coupling values of 10 and 20 dB are most common but for high power and pulsed systems, there can be a need for 40 dB coupling.
- Larger the coupling value smaller the coupled power.

COUPLING FACTOR:

- Directional couplers are specified in terms of the coupling accuracy at the frequency band centre.
- For example, a 10 dB coupling ± 0.5 dB means that the directional coupler can have 9.5 dB to 10.5 dB coupling at the frequency band centre.
- The accuracy is due to dimensional tolerances that can be held for the spacing of the two coupled lines.

- Another coupling specification is frequency sensitivity.
- A larger frequency sensitivity will allow a larger frequency band of operation.

ISOLATION FACTOR:

- Defined as the difference in signal levels in dB between the input port and the isolated port when the two other ports are terminated by matched loads.

$$I_{4,1} = -10 \log \left(\frac{P_4}{P_1} \right) \quad \text{dB}$$

- Also defined between the two output ports. In this case, one of the output ports is used as the input; the other is considered the output port while the other two ports (input and isolated) are terminated by matched loads.

$$I_{3,2} = -10 \log \left(\frac{P_3}{P_2} \right) \quad \text{dB}$$

ISOLATION FACTOR:

- The isolation between the input and the isolated ports may be different from the isolation between the two output ports.
- For example, the isolation between ports 1 and 4 can be 30 dB while the isolation between ports 2 and 3 can be a different value such as 25 dB.
- Isolation can be estimated from the coupling plus return loss.
- Larger the bandwidth, higher the frequency, difficult to provide Isolation.
- Higher the isolation, better (Ideally Infinite)

DIRECTIVITY:

- Indicates the coupler's ability to isolate the forward and backward waves.
- How well the forward travelling wave in the primary couples only to a specific port in secondary.

$$D_{3,4} = -10\log\left(\frac{P_4}{P_3}\right) = -10\log\left(\frac{P_4}{P_1}\right) + 10\log\left(\frac{P_3}{P_1}\right) \quad \text{dB}$$

where P_3 is the output power from the coupled port and P_4 is the power output from the isolated port.

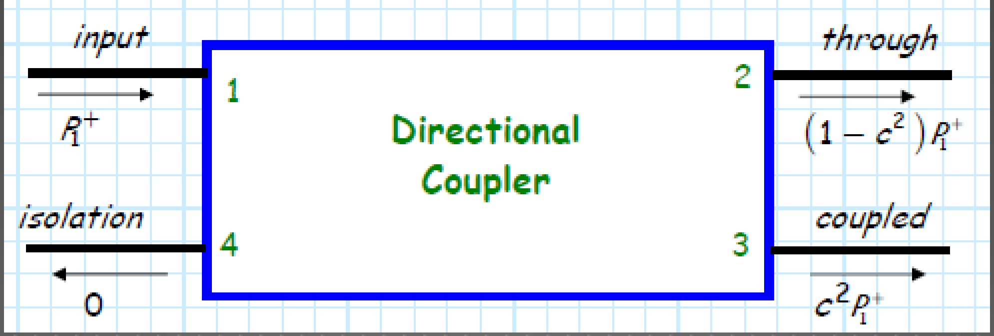
- The directivity should be as high as possible (Ideally Infinite).

DIRECTIVITY:

- The directivity is very high at the design frequency
- More sensitive function of frequency because it depends on the cancellation of two wave components.
- Waveguide directional couplers will have the best directivity.
- Directivity is not directly measurable, and is calculated from the difference of the isolation and coupling measurements as:

Directivity (dB) = Isolation (dB) - Coupling (dB)

$$D_{3,4} = I_{4,1} - C_{3,1} \quad \mathrm{dB}$$

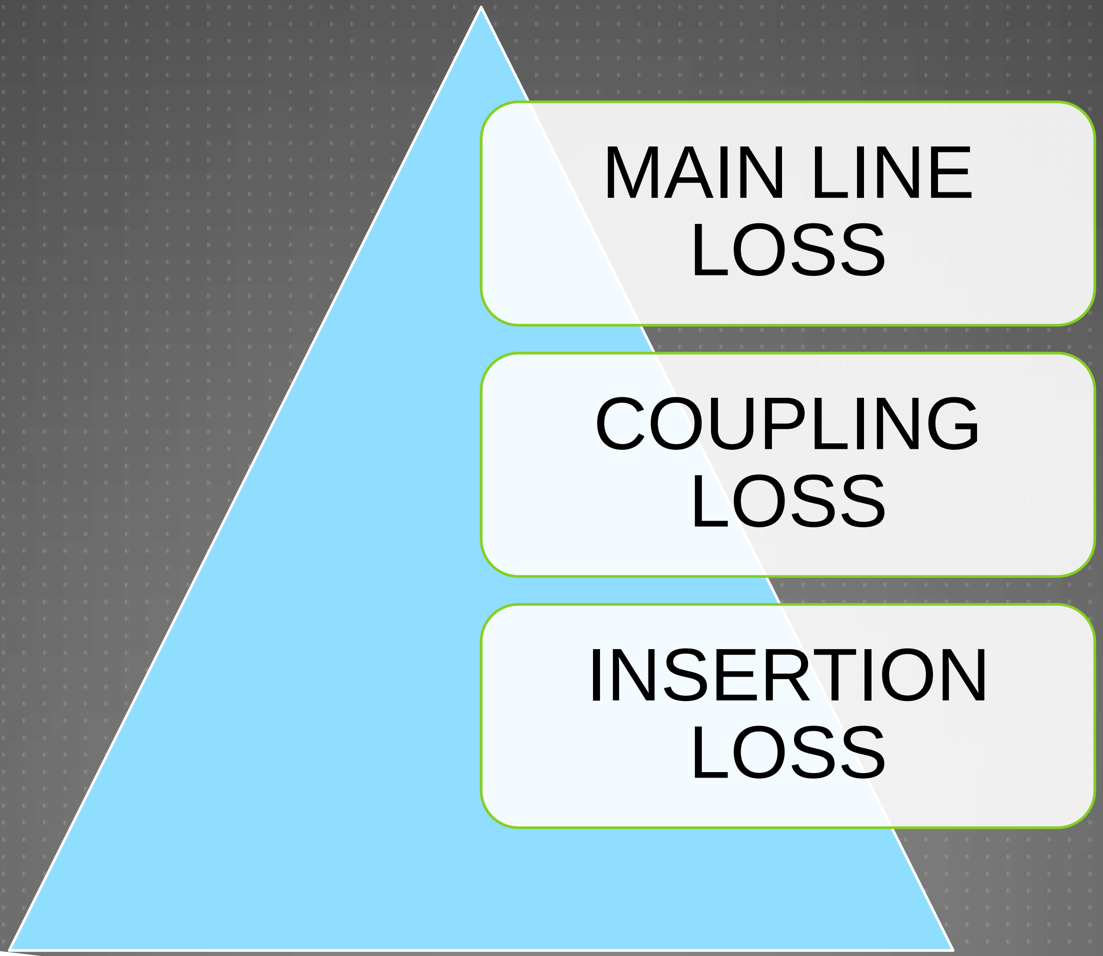


$$I(dB) = C(dB) + D(dB)$$

- Bidirectional property:

Input	Through	Coupled	Isolation
Port 1	Port 2	Port 3	Port 4
Port 2	Port 1	Port 4	Port 3
Port 3	Port 4	Port 1	Port 2
Port 4	Port 3	Port 2	Port 1

LOSSES:



MAIN LINE LOSS:

- Indicates the power loss as the signal travels from Input port to Through Port.

$$L_{i2,1} = -10 \log \left(\frac{P_2}{P_1} \right) \quad \text{dB}$$

- Ratio of input power through Input port (port1) to power out of the Through Port(port 2).

COUPLING LOSS:

- Indicates the portion of Mainline loss that is due to coupling some of the input power into the coupling port.

$$L_{c2,1} = -10 \log \left(1 - \frac{P_3}{P_1} \right) \quad \text{dB}$$

- This loss is unavoidable (conseration of energy)
- Very small value

Eg: coupling loss of 10dB coupler is 0.44dB

INSERTION LOSS:

- Ideally, P1-P3=P2 => Coupling loss=Mainline loss
- Practically, couplers are not perfectly lossless
- Additional losses due to absorbed energy(heat)

$$IL(dB) = ML(dB) - CL(dB)$$

- Indicates the portion of Mainline loss that is not due to coupling port.
- This is avoidable.
- Smaller the value, better.
- Very small coupling coefficients => coupling loss is so small that Mainline loss is almost entirely due to Insertion loss.

- The actual directional coupler loss will be a combination of coupling loss, dielectric loss, conductor loss, and VSWR loss.
- Depending on the frequency range, coupling loss becomes less significant above 15 dB coupling where the other losses constitute the majority of the total loss.

Coupling dB	Insertion Loss - dB
3	3.00
6	1.25
10	0.458
20	0.0436
30	0.00435

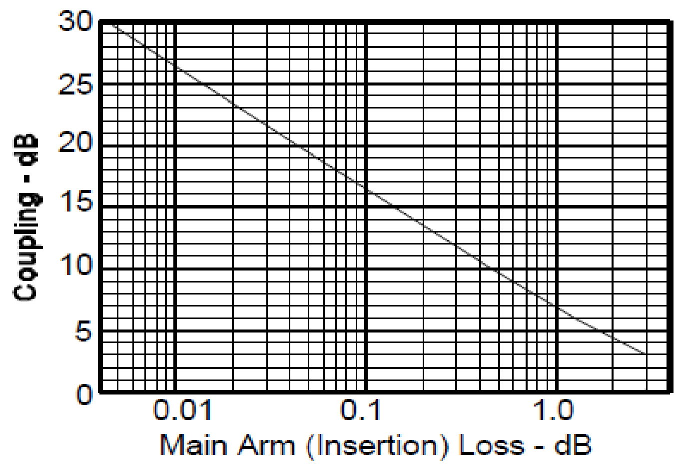


Figure 2. Coupling Insertion Loss

KEY SPECIFICATIONS:

- Directivity
- SWR
- Coupling Power
- Transmission loss
- Input Power

- SWR:

To minimise low mismatch errors and to improve measurement accuracy.

- Transmission loss:

Mainline loss- not important in low frequencies where most swept sources have sufficient power.

Broadband couplers have transmission losses of order 1dB

- Input power:

High power handling characterisitics of couplers are necessary when used for monitoring pulsated power systems.

TYPES OF COUPLERS:

Bethe-hole coupler:

- Waveguide directional coupler
- Uses a single hole
- Works over a narrow band.
- Reverse coupler, as opposed to most waveguide couplers that use multi-hole and are forward couplers.

Multi-hole coupler

- In waveguide, a two-hole coupler, two waveguides share a broad wall.
- The holes are 1/4 wave apart.
- In the forward case the coupled signals add, in the reverse they subtract (180 apart) and disappear.
- Coupling factor is controlled by hole size.
- The "holes" are often x-shaped, or perhaps other proprietary shapes.
- It is possible to provide very flat coupling over an entire waveguide band

TYPES OF COUPLERS:

Dual-directional coupler

- Two couplers in series, in opposing directions, with the isolated ports internally terminated.
- This component is the basis for the reflectometer.
- Using internal, well-matched loads helps remove errors associated with poor terminations that might be present in real systems.

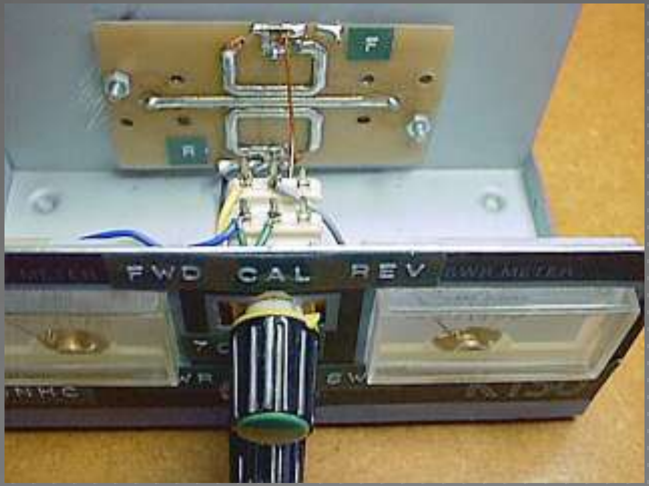
Hybrid couplers

- A hybrid coupler is a special case, where a 3 dB split is desired between the through path and the coupled path.
- There are two types of hybrid couplers, 90 degree couplers (such as Langes or branchlines) and 180 degree hy races and magic tees).

APPLICATIONS:

- **Monitoring / Power measurements**

The coupled output from the directional coupler can be used to monitor frequency and power level on the signal without interrupting the main power flow in the system.



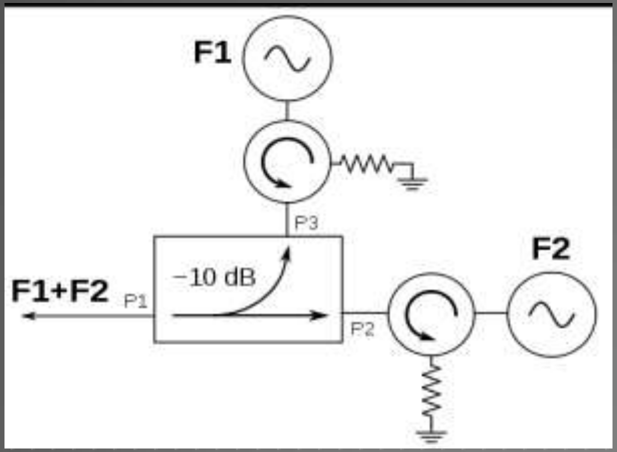
APPLICATIONS:

- Frequency measurements
- Signal levelling
- Reflection coefficient measurements
- Signal sampling
- Signal injection
- Measure incident and reflected power to determine VSWR

APPLICATIONS:

- **Making use of isolation-**

  If isolation is high, directional couplers are good for combining signals to feed a single line to a receiver.



COUPLER OR SPLITTER?

COUPLER	SPLITTER
4 port device	3 port device
Has one isolated port that is terminated	No isolated port
No internal resistors used	Uses internal resistors
Directional	Non-directional

OVERVIEW:

	Resistive Power Divider	Wilkinson Power Divider	Directional Coupler	Quadrature Hybrid
Physics of Operation	Resistive voltage divider circuit	Quarter-wave transformer separates even and odd mode signals with an isolation resistor	Weakly coupled quarter-wave transmission line sections	Strongly coupled quarter-wave transmission line sections
Low Frequency Range	DC	100s of MHz	100s of MHz	100s of MHz
High Frequency Range	10s of GHz	10s of GHz	10s of GHz	10s of GHz
Maximum Practical Bandwidth Ratios	Operates to DC	65:1	65:1	13:1
Insertion Loss (Nominal)	6 dB (assuming 2 outputs)	10 log (N) (where N = # of outputs)	10 log (1/ (1-10$^{(CPL/10)}$))	3 dB
Coupling Ratio	Equal Power (6 dB)	Equal Power (3dB)	6 dB to 30 dB	Equal Power (3dB)
Isolation	6 dB	20 dB (typical)	30 dB to 40 dB	20 dB (typical)
Directivity	NA	NA	20 dB (typical)	NA
Phase Shift @ Outputs	0° (In Phase)	0° (In Phase)	90° (usually not specified)	90°

THANK YOU..!!