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MULTI-PORT WAVEGUIDE ELEMENTS

Preliminary Information:

Directional Couplers: These are elements that can separately measure the incident and reflected waves on a line, generally consisting of two transmission lines: a main line and an auxiliary line. The main line and the auxiliary line are electromagnetically coupled to each other.

Directional couplers can be realized with coaxial, microstrip line, and transmission pipes (waveguides). Figure 1 shows a 3-port directional coupler realized with transmission pipes. In this coupler, a portion of the P1 power entering through port-1 is coupled as P3 power to port-3. The coupling and directivity of the coupler are calculated as:

$$\text{Coupling(C)} = 10\log\frac{P_1}{P_3} \text{ (dB)} \quad (1)$$

$$\text{Directivity(D)} = 10\log\frac{P_3}{P_4} \text{ (dB)} \quad (2)$$

The isolation between ports is:

$$\text{Isolation(I)} = 10\log\frac{P_1}{P_4} = C+D \text{ (dB)} \quad (3)$$

Directional couplers are widely used in various applications such as measuring reflection coefficient and standing wave ratio, determining the S-parameters of microwave transistors, and as attenuators. The 4th port of the 3-port directional coupler to be used in the experiment has been terminated with a matched load during manufacturing.

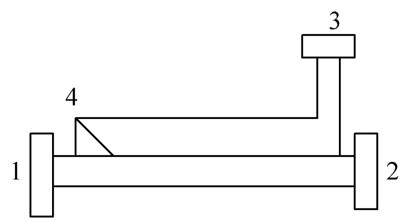

Figure 1: 3-port directional coupler

Ferrite Isolator: This component consists of a waveguide containing a piece of magnetized ferrite material adjacent to an ohmic metal sheet. Microwave power traveling in the forward direction experiences very little attenuation. However, power propagating in the reverse direction is absorbed by the ohmic sheet. Since the ferrite piece within the waveguide alters the field configuration in a unidirectional manner, it is also referred to as a field-displacement isolator.

Experimental Procedure:

1.1 Measurement of Coupling Value
1.1.1. Set up the experimental apparatus as shown in Figure 4 (at f=10 GHz). Set the rotary attenuator to 0 dB.
1.1.2. Take a reference reading on the DMM/meter.
1.1.3. Remove the directional coupler from the circuit and connect the detector in its place.
1.1.4. Increase the attenuation of the rotary attenuator until you obtain the reference value from step 1.1.2. The reading from the attenuator at this point is the coupling value.
1.2 Measurement of Directivity
1.2.1. In the setup from step 1.1.1, reverse the direction of the directional coupler. Set the rotary attenuator to 0 dB and take a new reference reading on the DMM/meter.
1.2.2. Return the coupler to its original orientation.
1.2.3. Increase the attenuation of the rotary attenuator until you obtain the reference value from step 1.2.1. The reading from the attenuator at this point is the directivity value.

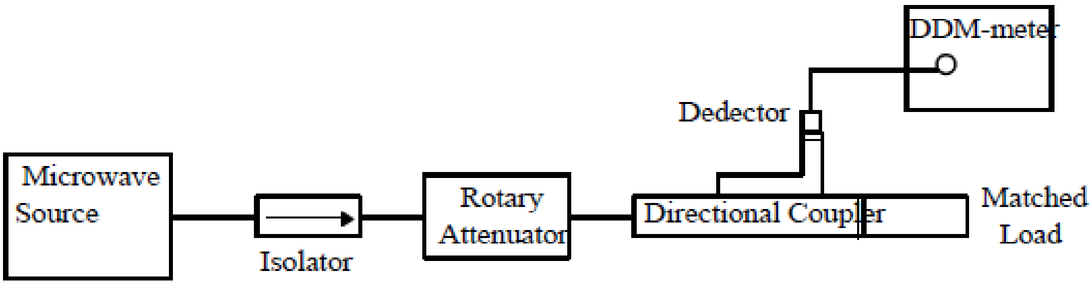

Figure 4: Experimental setup for measuring the coupling of a directional coupler

Pre-Laboratory Preparation Questions:

1. What is a directional coupler? Explain its structure and fundamental operating principle.
2. Define the concepts of coupling (C), directivity (D), and isolation (I) in a directional coupler, and write the mathematical relationship between them.
3. In a directional coupler used as a three-port device, what is the purpose of terminating the fourth port with a matched load? Explain.
4. What is a ferrite isolator? Explain its operating principle and why it is used in microwave systems.

Requirements for the Laboratory Report:

1. How can you measure both transmitted and reflected power simultaneously using a three-port directional coupler? Explain by drawing a simple block diagram.

2. What is the purpose of taking a reference measurement during coupling measurement and then removing the directional coupler from the circuit to connect the detector directly to the line? After this procedure, what physical quantity does the value read from the attenuator represent?
3. In directivity measurement, what is the physical meaning of reversing the direction of the directional coupler? Can directivity be measured correctly without performing this operation? Explain.