DIRECTIONAL COUPLER

Objective: To measure the directivity and coupling factor of a directional coupler

List of Equipment

1. Microwave source with square wave modulation
2. Isolator
3. Variable attenuator
4. Slotted line
5. Directional Coupler
6. Tunable detector
7. VSWR meter

Theory:

A directional coupler is a four-port microwave junction with the properties described below. With reference to Fig.1, which is schematic illustration or a directional coupler, the ideal directional coupler has the property that a wave incident in part 1 couples power into ports 2 and 3 but not into part 4. Similarly, power incident in part 4 couples into ports 2 and 3 but not into part 1. Thus ports 1 and 4 are uncoupled. For wave incident in port 2 or 3, the power also uncoupled. In addition, all four ports are matched. That is, if three ports are terminated in matched loads, the fourth port appears terminated in a matched load, and an incident wave in this port suffers no reflection.

Directional couplers are widely used in impedance bridges for microwave measurements and for power monitoring. Since these devices are required to operate over a band of frequencies, it is not possible to obtain ideal performance over the whole frequency band. The performance of a directional coupler is measured by two parameters –coupling and directivity. Let P_1 be the incident power in port 1 and left P_f be the coupled power in the forward direction in port 3. The coupling in decibels is then given by

$$C = 10 \log_{10} \frac{p_i}{p_f}$$

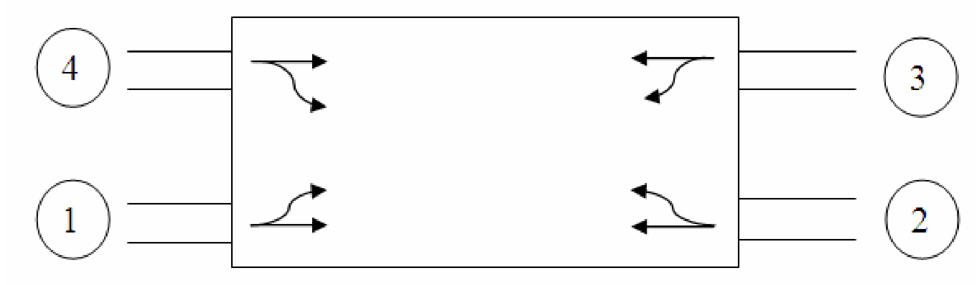


Figure 1

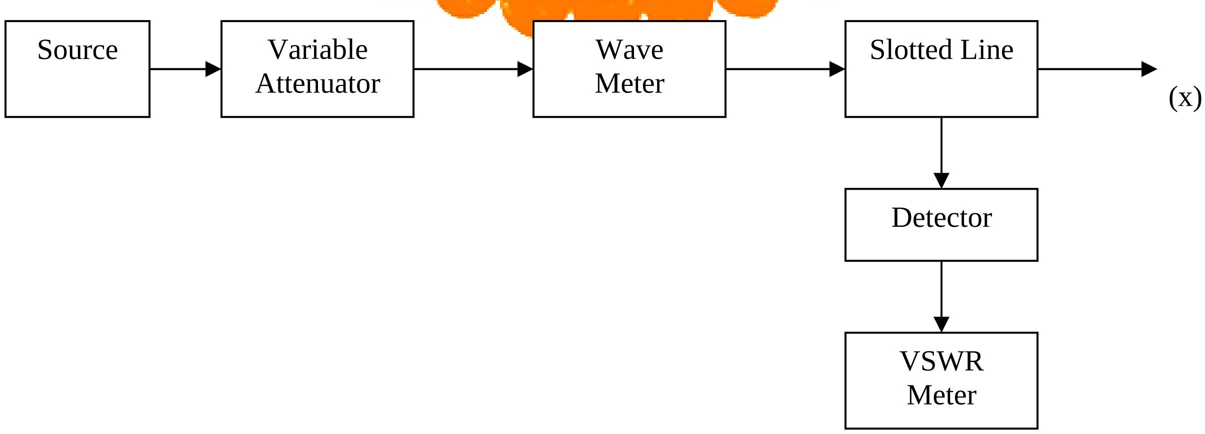
Ideally, the power p_b coupled in the backward direction in arm 4 should be zero. The extent to which this is achieved is measured by the directivity D, which is defined as

$$D = 10\log_{10}\frac{p_f}{p_b}$$

The directivity is a measure of how well the power can be coupled in the desired direction in the second waveguide.

A number of properties of the ideal directional coupler may be deduced from the symmetry and unitary properties of its scattering matrix.

The directional couplers are designed for a wide range of coupling factors, e.g., 3db, 10 db, 20db, 30db etc. The directivity of good coupler is about 30db. There is a great variety of ways of constructing directional couplers. A common type of directional coupler consists of two waveguides with suitable coupling apertures located in a common wall. With reference to Fig.1, sometimes, one of the ports, the port isolated from the input port, may be permanently match-terminated and therefore become inaccessible for any connections. A coupler is called a dual directional coupler when all four ports are accessible for connections.



Procedure:

1. Set the frequency of microwave source using slider. Use knob to fix the amplitude of the signal.
2. To modulate the signal vary the modulating frequency using slider, given in a square wave modulator.
3. Now press the button "**Forward direction**" in isolator so that signal can pass. Adjust the attenuation by using the slider.
4. We are using a Bethe Hole Coupler here. In lab we connect matched termination in two of the port (i.e. 2 and 4) and measure the output power p_f in port 3 while 1 acts as a input. Then we remove the coupler and directly measure the power p_i. From that we get coupling factor. While doing this, one can interchange power meter and matched load for ports 3 and 4 to find p_f and can get directivity corresponding to operating frequency.
5. But in simulation we directly get it. We can vary the "**Radius of the hole**" by using slider and can see the effect of changing radius in directivity and coupling factor also.
6. The power obtained in each port can be seen in the corresponding tab.
7. By varying frequency for a fix radius plot a graph of directivity and coupling factor versus frequency.

Discussion:

1. How does coupling occur in Directional Coupler?
2. How does the size and shape of hole affect the function of coupler?
3. What is forward and backward directional coupler? Explain working of phase difference coupler?
4. How do the directivity and the coupling factor of coupler vary with frequency?

References:

1. R.E. Collin, 'Foundations for Microwave Engineering', 1966.
2. K.C. Gupta, 'Microwaves', 1978.
3. R. Chatterjee, 'Elements of Microwave Engineering', 1984