الجامعة الإسلامية العالمية ماليزيا

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

يونيبرسيتي إسلام انتارابغسا مليسيا

# KULLIYYAH OF ENGINEERING

## DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

## MICROWAVE LABORATORY
## ECE 3203

### EXPERIMENT NO.5

**(Use of a Directional Coupler in Power Transmission and Reflective Measurements)**

## CONTENT

The properties of a waveguide directional coupler are investigated. It is confirmed that microwave power flowing in the forward direction (from source to load) and power flowing in the reverse direction (reflected from the load) may be independently detected using the directional coupler. In the practical assignment, the directional coupler is employed to measure the ratio of forward to reflected power for three different waveguide components and their VSWRs determined from these measurements.

## EQUIPMENT REQUIRED

| Qty | Identifying Letter | Description |
|---|---|---|
| 1 | - | Control console |
| 2 | A | Variable attenuators |
| 1 | F | Directional coupler |
| 1 | S | Probe diode-detector |
| 1 | N | Horn antenna |
| 1 | K | Resistive termination |
| 1 | R | Short-circuit termination plate |

## OBJECTIVES

When you have completed this assignment you:

- Will appreciate the properties of directional couplers and their applications in microwave transmission and measurement systems
- Know how a directional coupler may be used to monitor power flowing in forward and reverse direction
- Know how to measure the voltage standing wave ratio (VSWR) of a waveguide component using a directional coupler

## KNOWLEDGE LEVEL

Before you start this assignment it would be an advantage:

- To be familiar with the operation of the microwave bench
- To have read and done Assignment 2:- Measurement of Voltage Standing Wave Ratio (VSWR).
- To know that microwave signals can be detected using a diode detector and for low-level signals that the detector output is proportional to power.

## INTRODUCTION

A directional coupler consists essentially of two coupled transmission line designed to couple a certain fraction of energy from one line to the other and in a direction dependent on the direction of power flow. These properties are best defined with reference to the diagram of Figure 2-6-1.

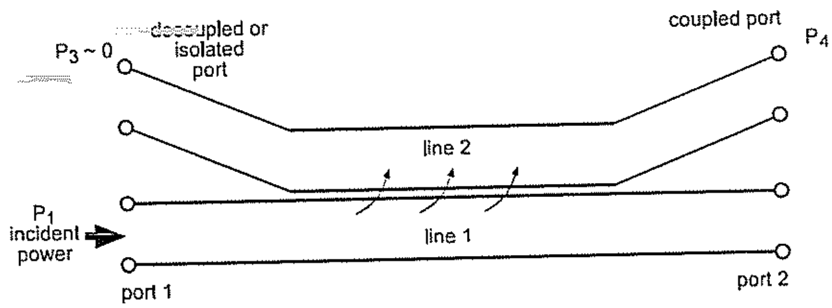


**Figure 2-6-1**

A fraction of the incident power $P_1$ entering port 1 and flowing in line 1 is coupled into line 2. The power coupled $P_3$ emerges at port 3 only with ideally zero power emerging at port 4. The balance of the power $P_2$ in line 1 emerges at port 2.

The coupling coefficient of the device,

$$C = \frac{\text{power to coupled port}}{\text{incident power}} = \frac{P_3}{P_1}$$

is usually expressed in decibels as

$$10 \log P_1/P_3 \text{ dB}$$

the reciprocal ratio $P_1/P_3$ rather than $P_3/P_1$ being used to avoid a negative quantity e.g. if the incident power $P_1$ = 10 mW and the power coupled to port 3, $P_3$ = 0.1 mW:

coupling C = 0.1/10 = 0.01

coupling in dB = 10 log10/0.01 = 20 dB

In practice, there is a small leakage of power to the 'isolated' or 'decoupled' port, port 4. The directional coupling quality of a coupler the directivity is defined in terms of the ration of coupled to decoupled port powers i.e.

$$\text{directivity D} = \frac{\text{power to coupled port}}{\text{power to isolated port}} = \frac{P_3}{P_4}$$

and is usually expressed in decibels,

$$10 \log P_3/P_4$$

Well-designed couplers typically have directivities in excess of 30 dB so that the ration of powers coupled in wanted to unwanted directions is usually better than 1000 in such devices.

Directional couplers find important application in power monitoring, power splitting and in microwave measurement systems. Some examples of their application are illustrated in Figure 2-6-2.

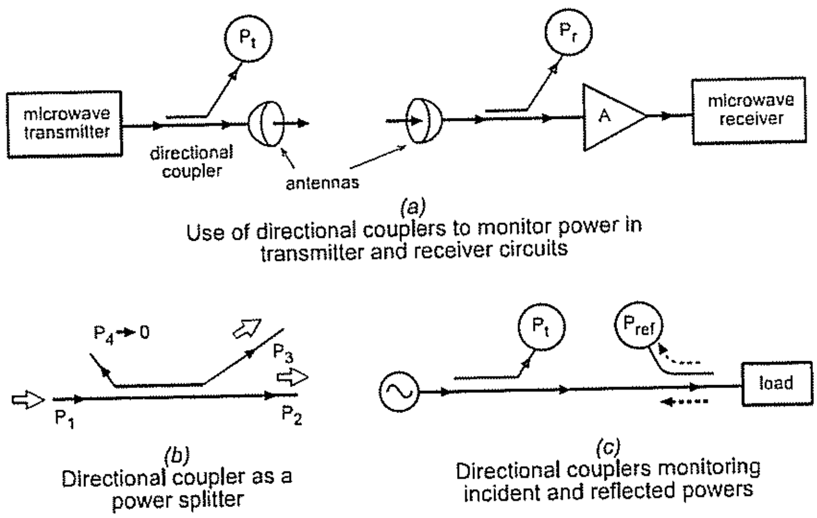


**Figure 2-6-2: Directional Coupler Applications**

The type of coupler used in this assignment is a side wall waveguide coupler where coupling is produced by cutting apertures in the side wall of two parallel waveguides. Microwave energy is coupled from one guide to the other via these apertures. The strength of coupling is determined by the position and area of the apertures and the directional properties by their axial spacing. A sketch of a simple 2-hole coupler of the type used in the assignment is shown in Figure 2-6-3. Its action is explained in the following paragraph.

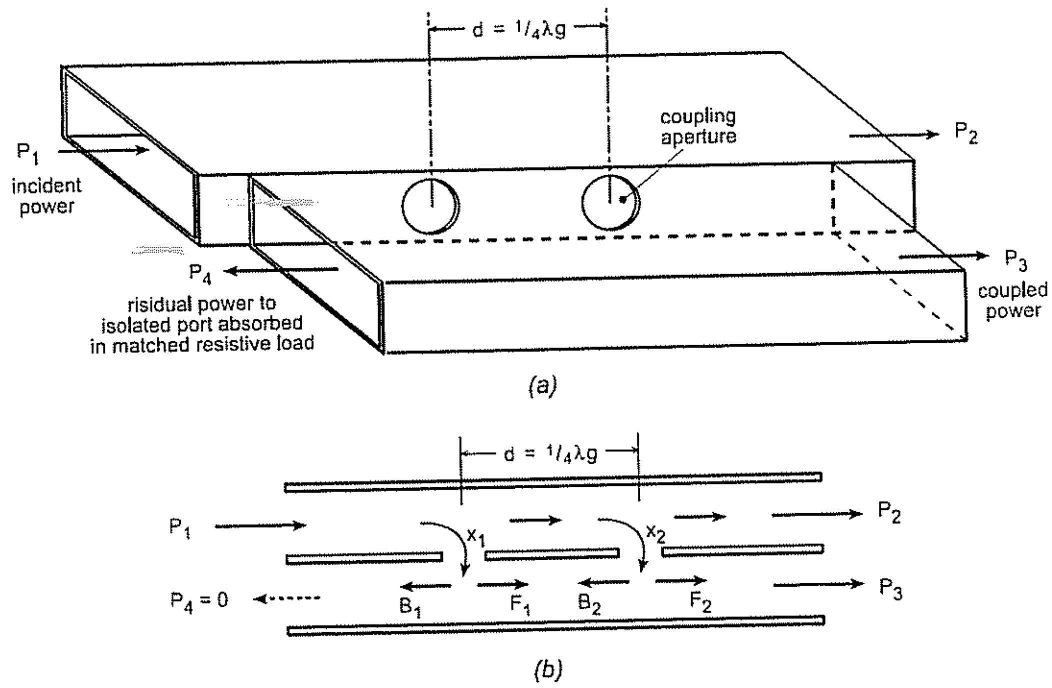


**Figure 2-6-3: Sidewall Coupler**

Consider waves incident at port 1 and suppose coupling through the first aperture produces waves of amplitude $F_1$ and $B_1$ in forward and reverse directions as indicated in Figure 2-6-3(b). Suppose at the second aperture coupling produces forward and reverse waves of amplitude $F_2$ and $B_2$. The components $F_1$ and $F_2$ from the apertures in the forward direction emerging at port 3 are in-phase since both have travelled the same distance d. Components $B_1$ and $B_2$ travelling in the reverse direction and emerging at port 4, however, differ in phase since $B_2$ has travelled an additional distance of 2 d when it combines with $B_1$ at port 4, i.e. from $x_1$ to $x_2$ and $x_2$ to $x_1$. Since d is designed to be ¼ lg, 2d = ½ lg and hence the components are 180° out of phase and therefore tend to cancel. If the coupling through the apertures is such that $B_1 = B_2$, then the cancellation will be complete and no power will emerge at port 4.

## EXPERIMENTAL PROCEDURE

> **WARNING:**
>
> Always avoid looking directly into an antenna or open waveguide components when energised. Microwave radiation can cause harm and eyes are particularly sensitive.

1. Connect up the equipment with the horn antenna as the effective load and with the directional coupler in the forward coupling position as shown in Figure 2-6-4.

   The probe diode-detector S detects the power coupled in the forward direction. The depth of penetration can be adjusted by the nut and should be close to maximum.

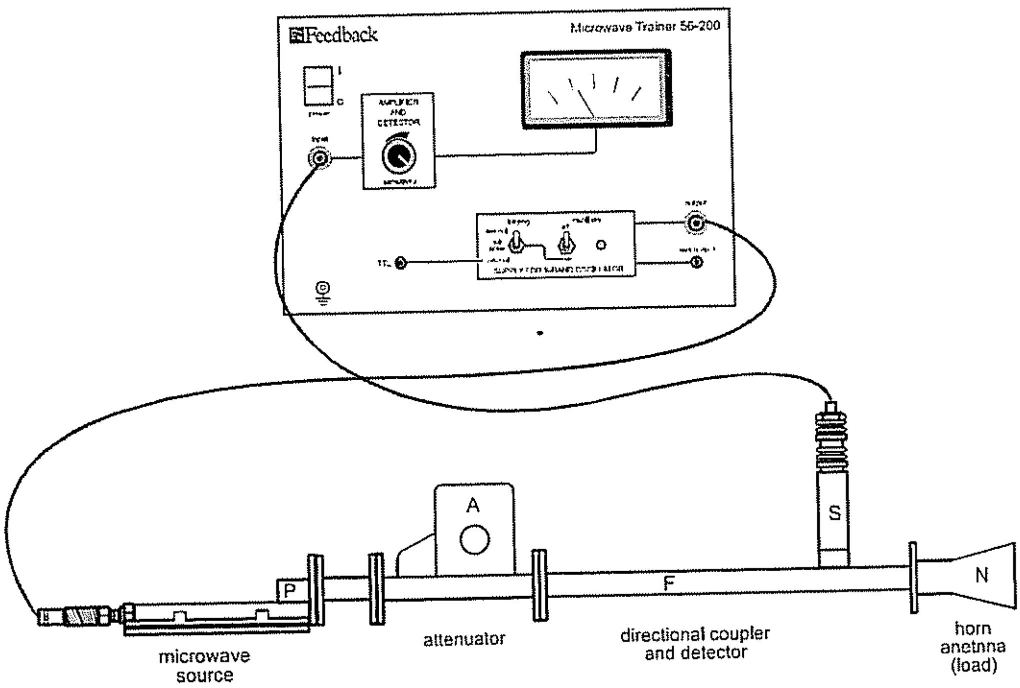


Figure 2-6-4

2. Set the attenuator to approximately 40°, switch the X-band source to internal keying and the meter to detector output. Switch on the console power supply and X-band oscillator source.

3. Adjust the amplifier-detector sensitivity control and if necessary the attenuator to obtain a reasonable (mid-scale) reading on the meter. Record the detector current in a table similar to that given above. This result provides a reference directly proportional to the power incident on the horn antenna load.

| Detector meter current, mA | HORN ANTENNA | RESISTIVE TERMINATION | ATTENUATOR PLUS SHORT-CIRCUIT |
|---|---|---|---|
| forward direction, $I_f$<br>reverse direction, $I_r$ | | | |
| power reflection coeff.<br>$P_r/P_i = I_r/I_f = \Gamma^2$ | | | |
| voltage reflection<br>coefficient, $\Gamma = \sqrt{(I_r/I_f)}$ | | | |
| VSWR, $S = \dfrac{1 + \Gamma}{1 - \Gamma}$ | | | |

**Figure 2-6-5: Table to Record Results**

4. Next reverse the directional coupler to measure the power reflected from the horn antenna. The directional coupler is now positioned to couple power flowing in the reverse direction. The set-up is shown in Figure 2-6-6.

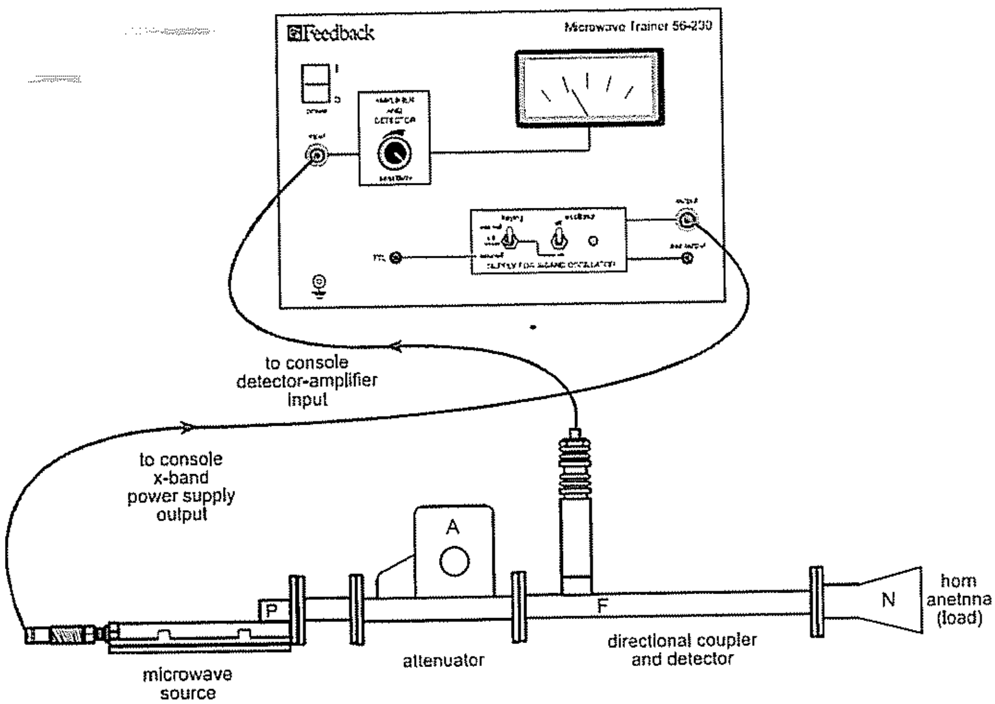


Figure 2-6-6

5. Measure the detector current output for the reverse direction case and record in the table under the HORN ANTENNA section.

6. Disconnect the horn antenna and replace with the resistive load termination. Measure detector current output for both forward and reverse coupling direction as indicated in 3, 4, 5 above.

7. Repeat with the above measurements for the case of a highly reflective load using a variable attenuator set at 80° (very low attenuation) terminated by a short circuiting plate.

8. For each of the 3 loads work out the following:

power reflection coefficient, $\frac{P_r}{P_i} = \frac{I_r}{I_f} = \Gamma^2$

voltage reflection coefficient, $\Gamma = \sqrt{\frac{P_r}{P_i}} = \sqrt{\frac{I_r}{I_f}}$

voltage standing wave ratio, VSWR S = $\frac{1+\Gamma}{1-\Gamma}$

and record your results in the table

10. Comment on the results obtained for each component as regards the degree of matching it presents to its waveguide feed line.

**SUMMARY**

The directional properties of a waveguide coupler have been investigated by measuring the ratio of powers coupled in forward and reverse directions for 3 different components. From these results, the VSWRs of the components were determined. Applications of directional couplers and construction for a typical coupler have also been considered.