"POINTS TO PONDER"

P Cube Inc.

COAXIAL DIRECTIONAL COUPLERS AND VSWR MEASUREMENT

The basic construction of the loop type directional coupler is shown in the diagram below.

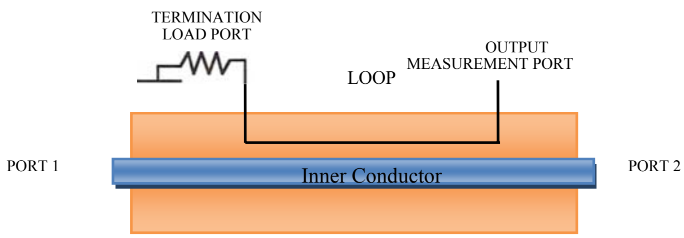

Figure 1

Power flowing in either direction in the main line inner conductor induces power to flow in the loop by means of inductive and capacitive coupling.
In the ideal directional coupler the amount of inductive and capacitive coupling is set so that a specified fraction of the power flowing in the main line from port 1 toward port 2 appears at the output port. This specified fraction, expressed in dB, is the directional coupler's coupling coefficient or coupling. It is defined as ratio of the induced power in the loop to the power flowing from port 1 to port 2 in the main line. In the ideal directional coupler, any power flowing in the main line in the opposite direction will have no effect on the amount of power appearing at the coupler's output port.

Ideal couplers are not possible and in practice power flowing in the main line in the direction opposite to that which we desire to measure will affect the amount of power at the coupler's output port. The ratio in dB of the power output at the coupler's output port, when power is flowing in the d esired direction, to the power output at the output port, when the same amount of power is flowing in the opposite direction, is defined as the directivity of the coupler. An ideal directional coupler has infinite directivity.

P Cube Inc. directional couplers can be specified with coupling values from 20 to 60 dB and directivities in excess of 35dB.

A standard technique used to measure VSWR in RF systems is to use a pair of directional couplers to measure the forward and reverse power at the point of interest and then compute the VSWR using the formula:

$$VSWR = \frac{1.0+(P_R/P_F)^{1/2}}{1.0-(P_R/P_F)^{1/2}}$$

In this section we discuss the effect of the directional couplers' directivity on the accuracy of the results obtained using this technique.

Consider the loop type directional coupler shown in figure 2 above. Suppose that power in the coaxial line flows into port 1 and out port 2. Assume that port 2 is terminated with a perfect load, i.e. there is no power flowing in the opposite direction and further assume that the termination load is perfect also, i.e. there is no power being reflected from it toward the output port. Let the voltage at port 1 be V1. If k is the coupIing factor then the voltage at the termination load port will be kV1 and the voltage at the sensor port will be kdV1, where d is the directivity factor. Directivity is defined as:

$$D = 10 \log (P_L/P_O)$$

where P_L is the power at the load port and P_O is the power at the output port. Note that, since

$P_L < P_O$, D is a number that is less than 0 (zero). And, since power is proportional to the square of The voltage:

$$D = 20 \log (V_L/V_O) = 20 \log (kV/kdV1) = 20 \log (l/d)$$

Solving for d in terms of D:

$$d = 10^{0.05(D)}$$

From this we can see that d is a number between 0 and 1. For a coupler with infinite directivity, the directivity factor is O.

For the coupler shown in Figure 1 assume that the power flowing from port 1 to port 2 is forward power and that port 2 is now terminated with a system load having a reflection coefficient p. In this configuration the coupler is being used to measure reverse power. The voltage at the output port is now a combination of the voltage due to the directivity effect and that due to the reflection from the system load. These voltages are KdV_I and KpV_1 and they combine vectorially. Thus the voltage at the output port will have a maximum and minimum given by

$$V_O = kpV_1 \pm kdV_1 = kV_1(p \pm d)$$

In general, for a directional coupler being used to measure reverse power, if we let V F be the forward power voltage and V R be the reverse power voltage then the voltage at the output port is

$$V_{OR} = k(V_R \pm dV_F)$$

When the coupler is being used to measure forward power the voltage at the sensor port is

$$V_{OF} = k(V_F \pm dV_R)$$

With a directivity of 35dB the directivity factor d is 0.018. When measuring normal forward power values with a directional coupler having 35dB directivity we can safely ignore the effect of the term kdV R since the forward voltage will be so much larger than the reverse.

However, when measuring reverse power we cannot ignore the effect of directivity. In this case the error is a fraction of the forward voltage and it is possible for the error term to be larger than the quantity we are trying to measure.

To see how the reverse coupler directivity affects the measurement of return loss using power readings obtained from a pair of directional couplers we proceed as follows.

Return loss is computed from the formula below where P F is forward power and P R is reverse power

$$L = 10 \log(P_R/P_F)$$

If we express the ratio of reverse to forward power in terms of voltages we see from our previous work that

$$L = -20 \log(p \pm d)$$

If we are using directional couplers having 35dB directivity to measure forward and reverse power then we obtain the following results when attempting to measure an actual return loss of 32.25dB (r = 0.024 and a 1.05 VSWR).

$$L_{min} = -20\ 10g(0.024 - 0.018) = -24.45$$

and

$$L_{max} = -20\ 10g(0.024 + 0.018) = -44.45$$

The corresponding VSWR values are approximately 1.09 and 1.01 and we have an uncertainty of approximately 0.04 in our measurement.

At a return loss of -20.8dB (corresponding to a 1.20 VSWR) the computed VSWR value will be in the range 1.16 to 1.24, again an uncertainty of approximately 0.04 in our computed VSWR.

The graph in Figure 2 below shows the maximum and minimum actual VSWR as a function of the VSWR computed from power measurements made with directional couplers having 35dB of directivity.

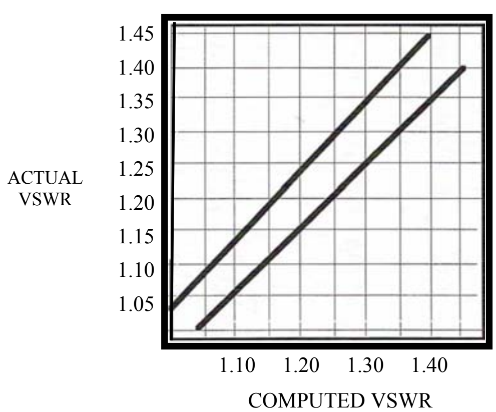

Figure 2