Mini-Circuits®

Coupler Theoretical Main-Line Loss Calculation (AN-30-004)

1. Introduction

The main-line loss of a coupler is defined as the loss between the input and output ports. Theoretical loss is defined as that of a perfect (lossless) coupler, for which the input power is the sum of the (main-line) output power and the power at the coupled port. Therefore, the theoretical main-line loss is dependent upon the fraction of the input power that is outputted at the coupled port. The conversion between them can be expressed mathematically. This application note derives the formula and provides a conversion table.

2. Derivation

A lossless coupler transfers all input power to the output and coupled ports:

$$P_{in} = P_{out} + P_{coupled} \quad (1)$$

In practice, positive decibel values are given for main-line loss and coupling (the fraction of the input power that is outputted at the coupled port):

$$\text{ML (main-line loss in dB)} = 10 \log_{10}(P_{in} / P_{out}), \text{ and} \quad (2)$$

$$\text{CPL (coupling in dB)} = 10 \log_{10}(P_{in} / P_{coupled}) \quad (3)$$

With these three equations, the CPL to ML conversion can be obtained.

$$\text{From equation (1), } P_{out}/P_{in} = 1 - P_{coupled}/P_{in} \quad (4)$$

$$\text{From equation (3), } P_{coupled}/P_{in} = 10^{-CPL/10} \quad (5)$$

Substitute (4), and then (5), into (2):

$$ML = 10 \log_{10}(P_{in} / P_{out}) = 10 \log_{10}[1/(1 - P_{coupled}/P_{in})]$$

$$= 10 \log_{10}[1/(1 - 10^{-CPL/10})] \quad (6)$$

3. Insertion Loss vs. Coupling table

Coupling dB	Insertion Loss dB
3	3.021
3.5	2.570
4	2.205
4.5	1.903
5	1.651
5.5	1.438
6	1.256
6.5	1.101
7	0.967
7.5	0.850
8	0.749
8.5	0.661
9	0.584
9.5	0.517
10	0.458
10.5	0.405
11	0.359
11.5	0.319
12	0.283
12.5	0.251
13	0.223
13.5	0.198
14	0.176
14.5	0.157
15	0.140
15.5	0.124
16	0.110
16.5	0.098

Coupling dB	Insertion Loss dB
17	0.088
17.5	0.078
18	0.069
18.5	0.062
19	0.055
19.5	0.049
20	0.044
20.5	0.039
21	0.035
21.5	0.031
22	0.027
22.5	0.024
23	0.022
23.5	0.019
24	0.017
24.5	0.015
25	0.014
25.5	0.012
26	0.011
26.5	0.010
27	0.009
27.5	0.008
28	0.007
28.5	0.006
29	0.005
29.5	0.005
30	0.004