DALLAS MAXIM

CATV Minimum Loss Pad for 75-ohm Measurements

CATV systems based on 75-ohm transmission lines are measured with 50-ohm test equipment. This article derives the equations relating pad networks that allow proper voltage and power measurement. A sample is given which computes the resistors needed in a 75 ohm to 50-ohm pad. The power loss from this pad is 5.72dB.

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Scope

Maxim has pioneered the development of a family of fully-integrated satellite DBS tuner ICs, and cable upstream amplifiers. These tuner inputs come from a 75Ω IF cable from the head-end LNB, operating over a band range of 950 to 2150MHz. The upstream amplifier ICs operate in a range of 5 to 42MHz, connecting through a balun to the 75Ω CATV cable infrastructure. These type of products require wideband port connections and measurements in a 75Ω environment. RF laboratory equipment offers a 50Ω measurement environment, so it is useful and necessary to provide an inexpensive conversion to between 50 and 75Ω ports.

Introduction

Minimum loss pads (MLPs) are used quite frequently in CATV measurement systems. When working with MLPs it is imperative to know whether voltage or power loss is being measured. For a minimum loss pad the power loss is different than the voltage loss, due to the impedance transformation ratio.
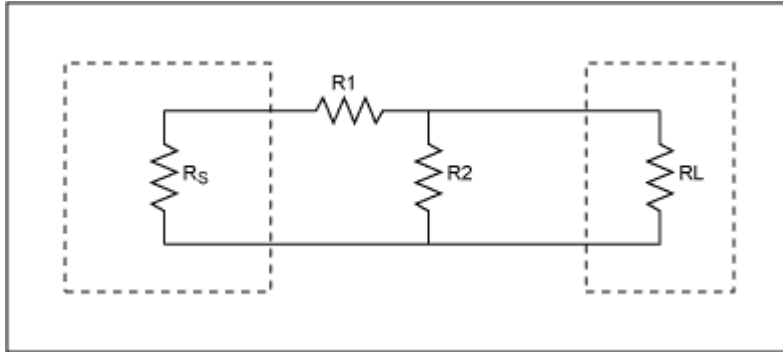
Minimum Loss Pad Calculation

Figure 1. Minimum loss pad

Figure 1 shows an MLP with source and load impedances of Rs and RL. An L-section pad is used to pad the high-impedance Rs to the low-impedance RL.

The following equations (EQN1,2,3) characterize the MLP of Figure1[1].

Assume Rs>RL

$$R_1 = R_S - R_2 \parallel R_L \qquad\qquad\qquad\qquad \text{EQN1}$$

$$R_2 = \sqrt{\frac{R_S R_L^2}{R_S - R_L}} \qquad\qquad\qquad\qquad \text{EQN2}$$

$$Loss_{POWER}(dB) = 20\log\left(\sqrt{\frac{R_S - R_L}{R_L}} + \sqrt{\frac{R_S}{R_L}}\right) \qquad\qquad \text{EQN3}$$

Voltage Loss

In CATV systems the power is measured in dBmV[2] and the concern is with voltage loss.

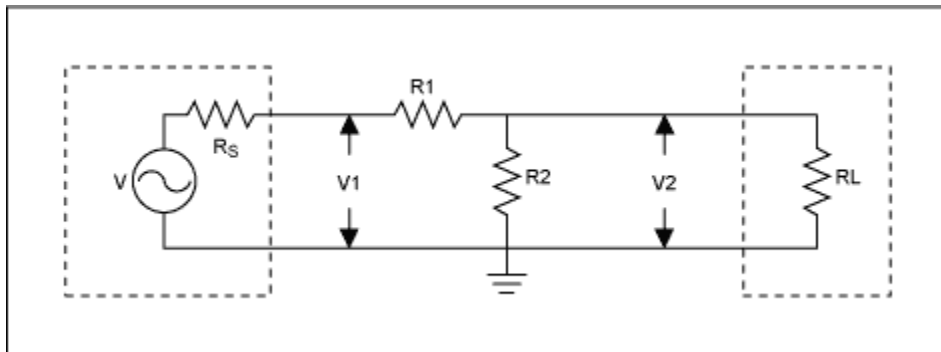*Figure 2. Minimum loss pad*

By inspection of Figure 2

$$V_2 = V_1 \left(\frac{(R_2 \parallel R_L)}{R_1 + (R_2 \parallel R_L)} \right)$$

EQN4

$$\frac{V_2}{V_1} = \left(\frac{(R_2 \parallel R_L)}{R_1 + (R_2 \parallel R_L)} \right)$$

EQN5

$$Loss_{VOLTAGE}(dB) = 20Log \left(\frac{(R_2 \parallel R_L)}{R_1 + (R_2 \parallel R_L)} \right)$$

EQN6

Substituting EQN2 into EQN6 yield EQN6.1, which is in terms of Rs and RL.

$$Loss_{VOLTAGE}(dB) = 20Log \left(\frac{\left(\sqrt{\frac{R_S R_L^2}{R_S - R_L}} \parallel R_L \right)}{R_S} \right)$$

EQN6.1

Power Loss

Power loss will be shown to consist of voltage loss plus and impedance ratio term. Power loss will be calculated as the ratio of power delivered to power available [3][4]. Power available is the power available to a perfectly matched load (see Figure 3).
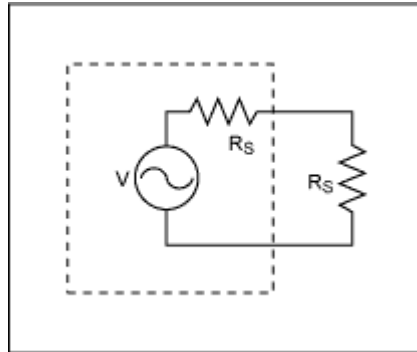

Figure 3. Power available

$$P_A = \left(\frac{V}{2} \right)^2 \left(\frac{1}{R_S} \right)$$

EQN7

$$P_A = \frac{V^2}{4R_S}$$

EQN8

By inspection of Figure 2, power is delivered to the load by

$$P_D = \frac{V_2^2}{R_L}$$

EQN9

$$V_2 = V\left(\frac{(R_2 \| R_L)}{(R_2 \| R_L) + R_S + R_1}\right)$$

EQN10

Substituting EQN10 into EQN9

$$P_D = V^2\left(\frac{(R_2 \| R_L)^2}{((R_2 \| R_L) + R_S + R_1)^2}\right)\left(\frac{1}{R_L}\right)$$

EQN11

$$Loss_{POWER}(dB) = 10Log\left(\frac{P_D}{P_A}\right)$$

EQN12

$$Loss_{POWER}(dB) = 10Log\left[\left(\frac{4R_S}{R_L}\right)\left(\frac{R_2 \| R_L}{R_2 \| R_L + R_S + R_1}\right)^2\right]$$

EQN13

$$Loss_{POWER}(dB) = 10Log\left[\left(\frac{R_S}{R_L}\right)\left(\frac{2(R_2 \| R_L)}{R_2 \| R_L + R_S + R_1}\right)^2\right]$$

EQN14

$$Loss_{POWER}(dB) = 10Log\left(\frac{R_S}{R_L}\right) + 20Log\left(\frac{2(R_2 \| R_L)}{R_2 \| R_L + R_1 + R_S}\right)$$

EQN15

Inspection of Figure 2 for a perfectly matched MLP

$$R_S = R_1 + R_2 \| R_L$$

EQN16

Substituting EQN16 into EQN15

$$Loss_{POWER}(dB) = 10Log\left(\frac{R_S}{R_L}\right) + 20Log\left(\frac{2(R_2 \| R_L)}{2(R_2 \| R_L + R_1)}\right)$$

EQN17

$$Loss_{POWER}(dB) = 10Log\left(\frac{R_S}{R_L}\right) + 20Log\left(\frac{(R_2 \| R_L)}{(R_2 \| R_L + R_1)}\right)$$

EQN18

Substituting EQN2 into EQN18 to solve in term of Rs and RL.

$$Loss_{POWER}(dB) = 10Log\left(\frac{R_S}{R_L}\right) + 20Log\left(\frac{\left(\sqrt{\frac{R_S R_L^2}{R_S - R_L}} \| R_L\right)}{(R_S)}\right)$$

EQN18.1

75-ohm/50-ohm MLP Example

To find the resistor values for a 75Ω to 50Ω MLP, use EQN1,2,3.

$$R_S = 75 \hspace{6cm} \text{EQN19}$$

$$R_L = 50 \hspace{6cm} \text{EQN20}$$

Confirm Rs > RL

$$R_2 = \sqrt{\frac{(75)(50)^2}{75-50}} \hspace{5cm} \text{EQN21}$$

$$R_2 = 86.6 \hspace{5.5cm} \text{EQN22}$$

$$R_1 = 75 - 86.6 \| 50 \hspace{4.5cm} \text{EQN23}$$

$$R_1 = 43.3 \hspace{5.5cm} \text{EQN24}$$

Using EQN18 the power loss can be calculated.

$$Loss_{POWER}(dB) = 10Log\left(\frac{75}{50}\right) + 20Log\left(\frac{(31.69)}{(31.69+43.3)}\right) \hspace{2cm} \text{EQN25}$$

$$Loss_{POWER}(dB) = 1.76 - 7.48 \hspace{4cm} \text{EQN26}$$

$$Loss_{POWER}(dB) = -5.72 \hspace{4.5cm} \text{EQN27}$$

Power loss for a MLP would be used when working with dBm's, for example. The dBm is a decibel unit that is related to power. In CATV, however, dBmV is typically used, which is a decibel relative to 1mV [2]. In this case, we would use voltage loss. Substituting the values for the 75/50Ω MLP into EQN6.

$$Loss_{VOLTAGE}(dB) = 20Log\left(\frac{(86.6\|50)}{43.3+(86.6\|50)}\right) \hspace{3cm} \text{EQN28}$$

$$Loss_{VOLTAGE}(dB) = -7.48 \hspace{4.5cm} \text{EQN29}$$

Conclusion

The power loss of an MLP is equal to the voltage loss plus the log of the impedance ratio, as shown in EQN18. By inspection of EQN18 and EQN6, the voltage loss is equal to the power loss when the source impedance is equal to the load impedance.

Use voltage loss when measuring dBmV, dBuV, dBV or any voltage related measurement. Use power loss when measuring with dBm or any power measurement.

References

[1] Bruno O. Weinschel, *Reference Data for Engineers: Radio, Electronics, Computer, and Communications*, Seventh Edition, Chapter 11.

[2] Maxim Application Note, *CATV dBm, dBmV, and dBuV Conversions* .
[3] Ziemer, Tranter, *Principles of Communications*, Third Edition, Appendix A, p.759-760.
[4] Krauss, Bostian, Raab, *Solid State Radio Engineering*, Chapters 2.

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