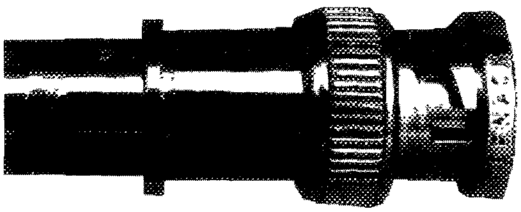
RF attenuators, terminations, matching pads, loads

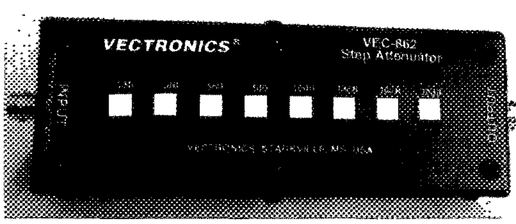
By Harold Kinley

The roles of RF attenuators, terminations, matching pads and loads are important in radio communications test and measurement, as well as in equipment interconnection.

A simple RF attenuator is shown in the photo below. This is an "in-line" BNC-type attenuator. This particular BNC attenuator is a 50Ω in/out with an attenuation of 3dB, but the attenuators are available in other impedances, connector



This is a 3dB, 50Ω attenuator, BNC style, from Pasternack Enterprises, Irvine, CA.



This is a 50Ω step attenuator. It is useful in many test and measurement procedures and general shop use.

types and attenuation levels. Figure 1 at the right shows the design of a 3dB pi-pad for a 50Ω system impedance. The table at the right shows the various arm- and leg-resistance values for various pi-pad attenuators for a 50Ω system impedance. A 50Ω step attenuator is shown in the photo at the left. Step attenuators generally use pi-pads that can be switched in or out to produce the desired level of attenuation for a temporary test setup or other temporary use.

Figure 2 at the right shows a diagram of a pi-pad or attenuator designed for a system impedance of 50Ω and an attenuation of 20dB. An attenuator pad will *smooth out* any impedance *bumps*, and the greater the attenuation of the pad, the greater the degree of *immunity* to impedance changes. For example, in Figure 2, if port B is left open, the impedance seen "looking" into port B will be 51Ω. If a short is placed between port A and ground, the impedance seen looking into port B will be 49Ω. The SWR in either case is 50 ÷ 49 = 1.02:1 or 51 ÷ 50 = 1.02:1. If a 50Ω impedance is connected from port A to ground, the impedance seen looking into port B will be 50Ω.

So, from this you can see the impedance-smoothing effect of an attenuator pad. Because this pad has an attenuation of 20dB, it has a pronounced smoothing effect on the impedance. In the example, an open, or short, changed the impedance by 1Ω from what it would have been with a proper 50Ω termination. In cases where the attenuator has a smaller amount of attenuation, the smoothing effect will be less.

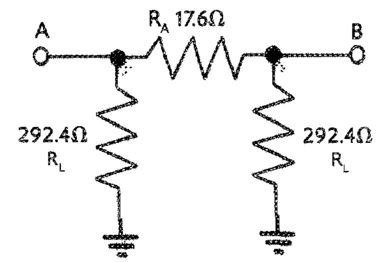


Figure 1. This is a 3dB attenuator pad designed for 50Ω system impedance. The arm and leg resistances are indicated by R_A and R_L, respectively.

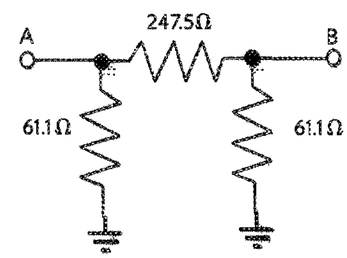


Figure 2. This pi attenuator is designed for 50Ω input/output with a 20dB attenuation. If port A is left open, and an ohmmeter is connected between port B and ground, then the ohmmeter will indicate 51Ω. If a short circuit is placed between port A and ground, then an ohmmeter will indicate 49Ω between port B and ground if a 50Ω impedance is connected between port A and ground, then a source 'looking' into port B will 'see' a 50Ω load. This shows the advantage of an attenuator pad. The impedance 'bump' is minimized, thus reducing the effect of any load mismatch on the equipment.

Table 1. Arm and leg resistances necessary to make a pi-pad with the given amount of attenuation level shown. This is for a system impedance of 50Ω. The two leg resistors are always equal for a simple attenuator pad.

Attenuation level (dB)	Arm resistor (ohms)	Leg resistors (ohms)
3	17.6	292.4
6	37.4	150.5
10	71.2	96.2
20	247.5	61.1

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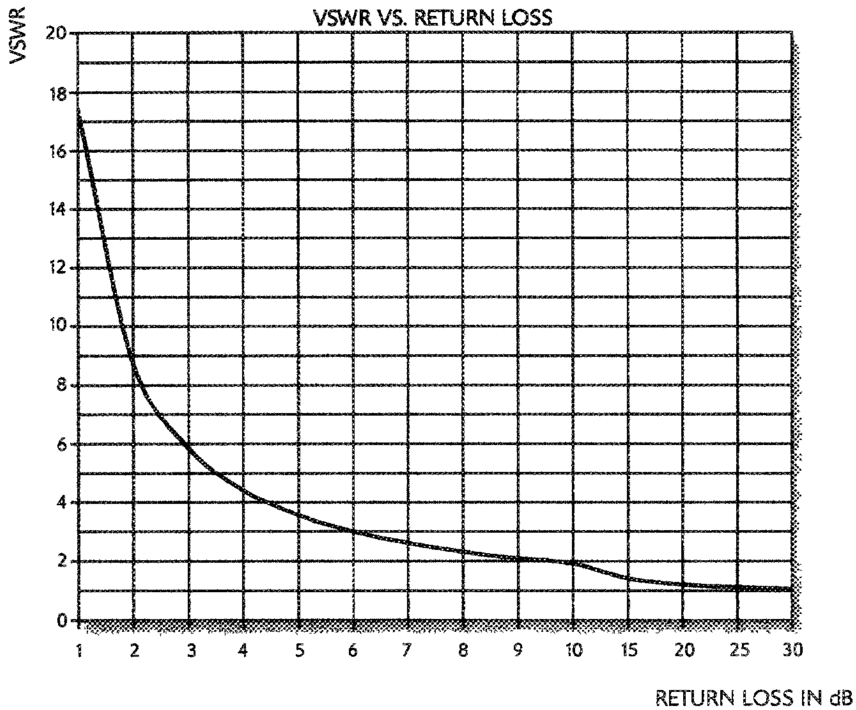


Figure 3. The correlation between SWR and return loss.

The smoothing effect can be described in terms of return loss. The return loss will be equal to twice the attenuation of the pad. For example, in the case of the 20dB attenuator pad, the return loss is 40dB, or twice the attenuation of the pad. This is because the incident signal travels through the pad, and the reflected signal travels back through the pad. So, the *forward-traveling* or incident signal is attenuated by the amount of attenuation of the pad, and then the reflected or *reverse-traveling* signal is attenuated by the amount of attenuation of the pad. So, the effect of the attenuation is doubled.

The graph at the left correlates SWR with return loss. It can be

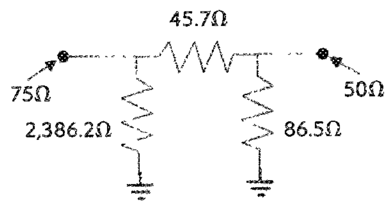


Figure 4. This pi-pad will match a 75Ω impedance to a 50Ω impedance with a loss of 6dB.

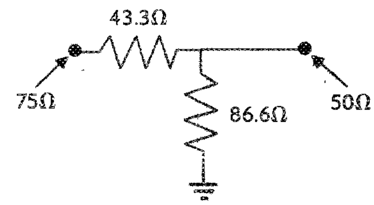


Figure 5. A minimum-loss L-pad used to match a 75Ω impedance to a 50Ω impedance. The loss is 5.7dB.

On the left is a 25W, 50Ω dummy load. On the right is a 50Ω termination.

used to determine the smoothing effect of a pad by doubling the attenuation of the pad and finding this return loss on the graph to convert it to SWR. Suppose we have a worst-case mismatch on one side of a 3dB pad. Because the return loss will be twice this amount, or 6dB, we know from the graph in Figure 3 that the worst-case mismatch will produce a SWR of 3:1 on the opposite side of the pad. Find 6dB on the return-loss scale, and note that it equates to a SWR of 3:1. Table 1 shows the value of arm and leg resistors used to make pi-pads for the attenuation levels shown on the chart. Two-leg resistors are used, but they are equal in value for a simple attenuator pad—that is, with equal input/output impedance.

Matching pads

Although simple attenuator

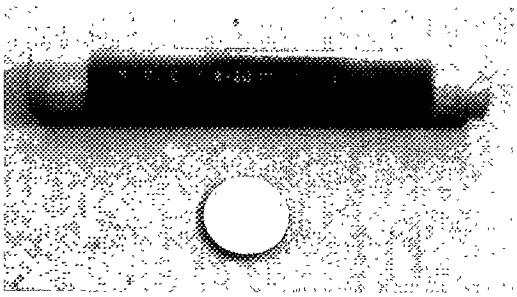
pads are used where the input/output impedances are equal, the resistive matching pad is used to *match* two impedances. Such resistive matching pads can be designed for minimum loss or for a loss greater than the minimum loss. A matching pad can't be designed for less than the minimum loss. For example, to match a 75Ω impedance to a 50Ω impedance, a minimum-loss pad can be used, or one greater than the minimum loss can be used. The minimum loss for such a matching pad is 5.7dB.

The Heath 'Cantenna' from the old HeathKit company uses transformer oil (or mineral oil with a derating factor) for cooling.

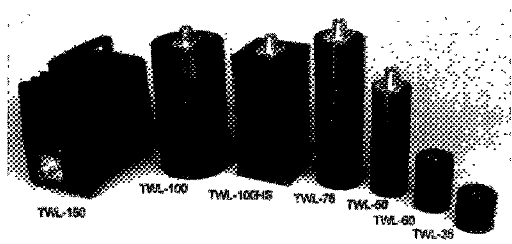
Figure 4 on page 28 shows a pi-pad designed to match a 75Ω impedance to a 50Ω impedance with a loss of 6dB. Figure 5 on page 28 shows an L-pad that is used to match 50Ω/75Ω impedances with a minimum loss of 5.7dB. For impedance-matching pi-pads, the *leg resistors are not equal*, while in simple attenuator pi-pads (where the input and output impedances are equal) the *leg resistors are equal*.

Terminations

What is the difference between a dummy load and a termination? Fundamentally, it is the amount of power that can be handled. A simple termination is generally considered to be a small-signal device. The photo on page 28 shows a 25Ω dummy load at the left and a termination at the right. While the dummy load could serve as a termination, the smaller termination could not serve in place of the dummy load except at small-signal power levels. Terminations that concern us in land mobile radio work are 50Ω terminations. Terminations are available in 75Ω as well. Terminations are used in such applications as terminating unused ports



This 50Ω load resistor is used in the Heath Cantenna.

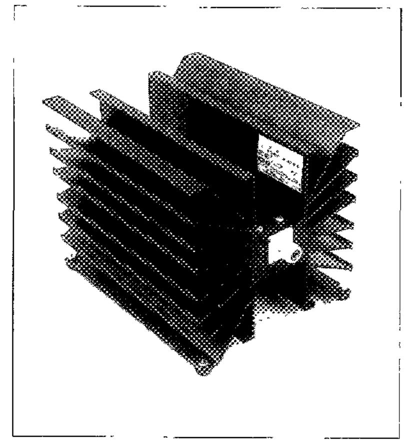


A variety of dummy loads of various shapes and sizes. Photo courtesy of Telewave, Mountain View, CA.

on signal combiners/dividers and receiver multicouplers.

Dummy loads

Transmitter testing requires that the transmitter be connected to a dummy load to prevent interference to other radios operating on the same frequency. The photo on page 30 shows a dummy load that uses transformer oil to cool the 50Ω load resistor. The resistor element used in this dummy load is shown in the first photo at the left. This load was made by the old HeathKit company and is no longer available. However, a similar load is available from MFJ Enterprises of Starkville, MS. The HeathKit 'Cantenna' also had a built-in detector that could supply a dc voltage that could be used as a power indicator. The unit featured a vent on top of the can in case of overheating of the transformer oil. The disadvantage of this type of dummy load is that



A 400W, 50Ω 'dry' dummy load, model TWL-400. Photo courtesy of Telewave, Mountain View, CA.

transporting it can become messy if the oil spills. Also, it can only be used in the upright position.

For a portable dummy load, the Telewave 400W dummy load shown in the photo above is a good choice. This is a dry load that is easily transportable and can be used in any position. The large radiating heat sink fins provide rapid cooling of the load. This particular load features a Type N connector.

The second photo at the left shows a variety of dummy loads of different shapes, sizes and uses. When choosing a dummy load, make sure you use one that can handle the full amount of transmitter power without over-heating in a reasonable amount of time. From time to time, check the resistance of the dummy load with an ohmmeter. Frequent overheating of the resistor element can damage the element and cause the resistance to change. Make sure it is close to 50Ω if it is designed for a 50Ω system.

Until next time—*stay tuned!* ■

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