Building VHF Power Attenuators

Paul Wade N1BWT

An attenuator or pad is frequently needed in ham equipment to reduce power, gain or signal levels. Tables of resistor values are available in most handbooks [1,2] so design is not difficult. However, if significant power handling is required, power resistors suitable for RF frequencies can be difficult to locate. The tables below and the computer program that generated them can be used to make do with available components.

For example, all my microwave transverters are designed to be driven with the two-watt output of an old IC-202, which is ideal for portable operation. When I wish to use them at home with a larger transceiver, or a friend wants to use one with a more modern rig, much more power is available. We could push the low-power button, adjust the output, and hope that we don't forget next time...

I prefer to make things fool-resistant (nothing is foolproof!) and avoid smoke. So a resistive attenuator is needed. A typical ten-watt transceiver for two meters delivers about 14 watts of output power at 13.6 volts, so about 8 dB of attenuation is necessary, capable of dissipating 14 - 2 = 12 watts.

The largest resistor that works well at two meters is a two-watt carbon composition type, but these aren't readily available anymore. A survey of the junk box and the local surplus emporium yielded only a few values of one and two watt resistors, so I had to design around these values.

Next, I had to figure out how much power is dissipated in each resistor. If we examine a pi attenuator, Figure 1, we can readily determine the voltage at each end from the attenuation:

    Vout = Vin * 10**(-dB/20).

Since all the resistors are connected to the ends or to ground, we know the voltage across each resistor, and power is just

    Power = V**2 / R.

The powers tabulated in Table 1 list the power dissipated in each resistor as a percentage of the input power - anything left over is the output power. These powers are correct only if the input and output impedances are close to the design value (usually 50 ohms), since reflected power from mismatches must also be dissipated.

For a T attenuator, Figure 2, we perform the same sort of calculation using the current in each resistor, but only a couple of calculations are necessary before we notice that the power in R1, R2, and R3 is the same for pi and T attenuators of the same attenuation. Thus, there is only one set of power numbers in Table 1.

Getting back to our example, in order to dissipate 12 watts in one and two watt resistors we must find series and parallel combinations that equal the required resistance and can handle the power. For an 8 dB attenuator, R2 must dissipate 43% of the input power, or about 6 watts.

On the other hand we could put together a series of small attenuators that added up to 8 dB, each dissipating a part of the power. For instance, a 1 dB attenuator only dissipates 20.5% of the input power, or about 3 watts total, of which about 1.5 watts is in R2. Obviously we could stack up eight 1-dB attenuators, or succeeding ones, which only have to handle the remaining power, could have higher attenuation.

What I did was to look at Table 1 and mark all the resistances for which I had something close. Then I marked the values I could approximate by paralleling two (half the resistance) or three (one-third) identical resistors, or two identical ones in series (twice the resistance). Now I had an idea which attenuators I could make; a few more calculations gave me an idea how much power each could handle. The final configuration was 1 + 3 + 4 dB, all of the pi type, as shown in Figure 3. The next step was to combine the end resistors of adjacent sections as shown in Figure 4, with the actual resistor combinations I used. Note that this combination is not bilateral - if the ends are reversed, smoke may result!

I built this unit in a small metal box with two coax connectors from a recent hamfest. The measured attenuation at two meters was 8.7 dB, with a VSWR of about 1.15. The output power was a bit less than I wanted, so I made small adjustments at the output end (so the VSWR was not affected much), ending up wiht the final values shown in Figure 4. Now the output power is exactly two watts, and the resistors are barely warm after several minutes with key down.

Conclusion

Using Table 1 and a hand calculator, you can quickly design an attenuator for any needed attenuation and power level, using available components. The program PAD.EXE may be used to calculate other attenuations, attenuators with input and output impedances other than 50 ohms, and values for Bridged-T type attenuators. For those inclined to computer programming, the source code is available [Appendix/floppy/ARRL bulletin board ???] for further improvement.

[1] ARRL Handbook for Radio Amateurs, ARRL, 1992, p 25-39.

[2] Reverence Data for Engineers: Radio, Electronics, Computer, and Communications, Seventh Edition, Sams, 1990, pp. 11-3 to 11-7.

Loss	T		pi		Power dissipation		
dB	R1,R3	R2	R1,R3	R2	R1	R2	R3
1	2.88	433.34	869.55	5.77	5.8%	10.2%	4.6%
1.5	4.31	288.1	580.5	8.68	8.6%	14.5%	6.1%
2	5.73	215.24	436.21	11.61	11.5%	18.2%	7.2%
2.5	7.15	171.34	349.83	14.59	14.3%	21.4%	8%
3	8.55	141.93	292.4	17.61	17.1%	24.2%	8.6%
3.5	9.94	120.79	251.52	20.7	19.9%	26.6%	8.9%
4	11.31	104.83	220.97	23.85	22.6%	28.6%	9%
4.5	12.67	92.32	197.32	27.08	25.3%	30.2%	9%
5	14.01	82.24	178.49	30.4	28%	31.5%	8.9%
5.5	15.32	73.92	163.17	33.82	30.6%	32.5%	8.6%
6	16.61	66.93	150.48	37.35	33.2%	33.3%	8.3%
6.5	17.88	60.96	139.81	41.01	35.8%	33.8%	8%
7	19.12	55.8	130.73	44.8	38.2%	34.2%	7.6%
7.5	20.34	51.29	122.92	48.74	40.7%	34.3%	7.2%
8	21.53	47.31	116.14	52.84	43.1%	34.3%	6.8%
9	23.81	40.59	104.99	61.59	47.6%	33.8%	6%
10	25.97	35.14	96.25	71.15	51.9%	32.9%	5.2%
11	28.01	30.62	89.24	81.66	56%	31.6%	4.5%
12	29.92	26.81	83.54	93.25	59.8%	30.1%	3.8%
13	31.71	23.57	78.84	106.07	63.4%	28.4%	3.2%
14	33.37	20.78	74.93	120.31	66.7%	26.6%	2.7%
15	34.9	18.36	71.63	136.14	69.8%	24.8%	2.2%
16	36.32	16.26	68.83	153.78	72.6%	23%	1.8%
17	37.62	14.41	66.45	173.46	75.2%	21.3%	1.5%
18	38.82	12.79	64.4	195.43	77.6%	19.5%	1.2%
19	39.91	11.36	62.64	220.01	79.8%	17.9%	1%
20	40.91	10.1	61.11	247.5	81.8%	16.4%	0.8%
21	41.82	8.98	59.78	278.28	83.6%	14.9%	0.7%
22	42.64	7.99	58.63	312.75	85.3%	13.5%	0.5%
23	43.39	7.12	57.62	351.36	86.8%	12.3%	0.4%

Table 1. Resistance and power dissipation for T and pi attenuators
with 50 ohm input and output impedance.

```
Input   -+---R2---+-   Rload
         |        |
         R1       R3
         |        |
         V        V
```

Figure 1. pi attenuator

```
Input   --R1--+--R3--  Rload
              |
              R2
              |
              V
```

Figure 2. T attenuator

```
Input -+---R2---+-----+---R2---+-----+---R2---+-  Rload
       |        |     |        |     |        |
       R1       R3    R1       R3    R1       R3
       |  1dB   |     |  3dB   |     |  4dB   |
       V        V     V        V     V        V
```

Figure 3. 1 + 3 + 4 = 8 dB attenuator

```
Input -+---R2---+---R4---+---R6---+-  Rload
       |        |        |        |
       R1       R3       R5       R7
       |        |        |        |
       V        V        V        V
```

Resistor	Design R	Design Power	Implementation
----	----	-----	--------------
R1	870 ohms	0.9 watt	2 parallel 1.8K 1/2 watt
R2	6	1.56	3 parallel 10 ohm 1 watt
R3	220	2.76	2 series 120 ohm 2 watt
R4	18	2.55	3 parallel 56 ohm 1 watt
R5	126	2.36	220 ohm 2 watt in parallel with 300 ohm 1 watt [final version: no 300 ohm]
R6	24	1.24	2 parallel 56 ohm 1 watt
R7	220	0.54	220 ohm 2 watt [final: 300 ohm 1 watt]

Figure 4. Actual 8 dB attenuator.