Technical Notes

Introduction to microwave attenuators

Nikkohm Sales Department

1. Introduction

There are many types of microwave attenuators. This section focuses on simple resistance attenuators. The simplest resistance attenuator is made of a resistor network of two input (1 port) and two output 2 terminals (1 port).

The main specifications of the attenuator are characteristic impedance (Ω) and attenuation (dB). Here describes the voltage attenuator, not power attenuator.

When the output terminal is terminated with the characteristic impedance, and when a signal Vo applies to input port of the attenuator.

Voltage V0 is less than the voltage of the Vi, the ratio of the input to output of 1/2 or 1/100 is called the voltage attenuation.

The attenuation of 1/10, 1/100, 1/1000 or, 0.1, 0.01 0.001 is used logarithm for simplification. In logarithmic notation, If the attenuation is half, the ratio is 0.5, and attenuation = -6 dB, and the attenuation is 1/100, and the ratio is 0.01, attenuation = - 40 dB. The formula is as follows,

$$Attenuation(dB) = ATT(dB) = 20\log\frac{Vo}{Vi}$$

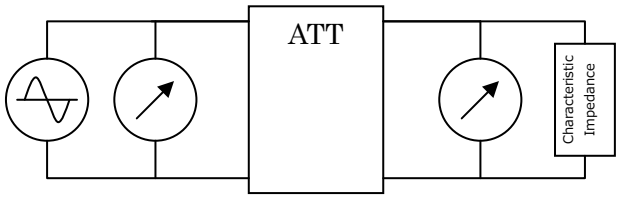

Figure 1. Attenuator

The reason above is 20 log ( ) instead of 10 log ( ) because it is the voltage ratio, so the power ratio is 10 log ( ).

Table 1 shows the relationship between voltage attenuation ratio and the voltage attenuation of decibels.

Ratio, X	LOG(X)	ATT(dB)
1.00000	0.000	0
0.50000	-0.301	-6.021
0.33333	-0.477	-9.542
0.25000	-0.602	-12.041
0.20000	-0.699	-13.979
0.16667	-0.778	-15.563
0.14286	-0.845	-16.902
0.12500	-0.903	-18.062
0.11111	-0.954	-19.085
0.10000	-1.000	-20
0.01000	-2.000	-40
0.00100	-3.000	-60
0.00010	-4.000	-80
0.00001	-5.000	-100

Table 1. Attenuation ratio and dB notation

The attenuator is commonly used in microwave electronics, such as transferring next stage by reducing the large signal voltage, and monitoring the amplification of the amplifier, matching impedance of drive stage to next stage with rejecting reflection.

The attenuators include a chip style attenuator, a through-hole attenuator, a coaxial fixed attenuator, and a step attenuator as shown in figure 2..

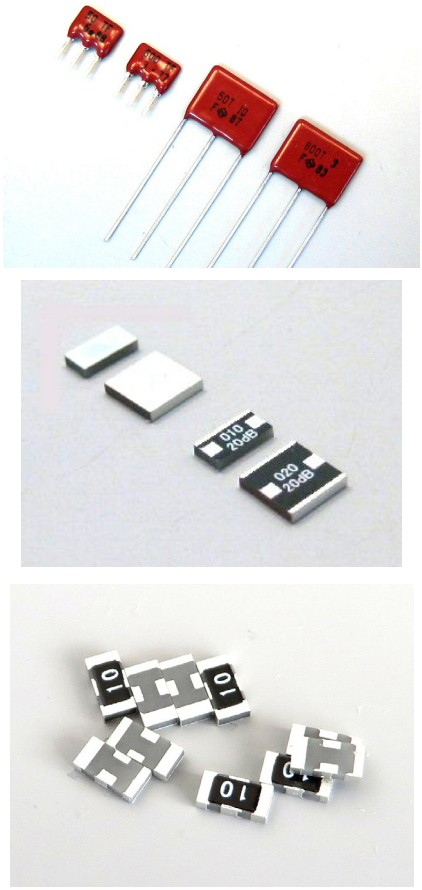

Figure 2. From upper, step attenuator, coaxial attenuator, through-hole attenuator, chip attenuator, typically.

2. The characteristic impedance of the attenuator and the series connection of the attenuator

Characteristic impedance 600Ω is used in wired telephone lines. The characteristic impedance 75 Ω is used for cable television. In many other applications, the characteristic impedance is 50Ω. In following explanation, the characteristic impedance is described as 50 Ω. The attenuation of the attenuator is not positive and it is negative, but in many cases, the negative sign (-) is omitted. In this case, we will omit the negative sign of attenuation below.

If the characteristic impedance is the same in all attenuators, the attenuators can be connected in series. In this case, the decibel expression can be added. In the example shown in Fig. 3, four attenuators are connected in series to achieve a 57 dB attenuator. Therefore, the attenuator manufacturer supplies attenuation attenuators such discrete values as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 16, 20, 30, 32, 40 dB. And, less than 1 dB tends to be not supplied because of less use.

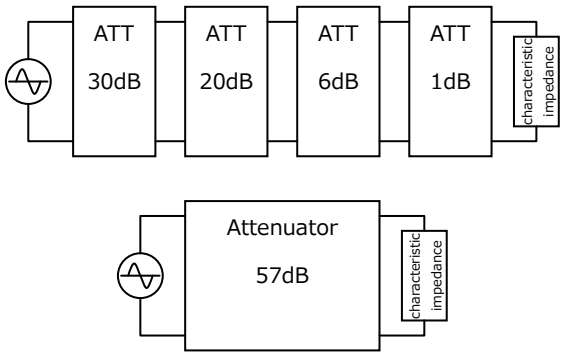

Figure 3. Series connection of attenuators

3. Resistive attenuators

The attenuator can be made by network of three resistor circuit.

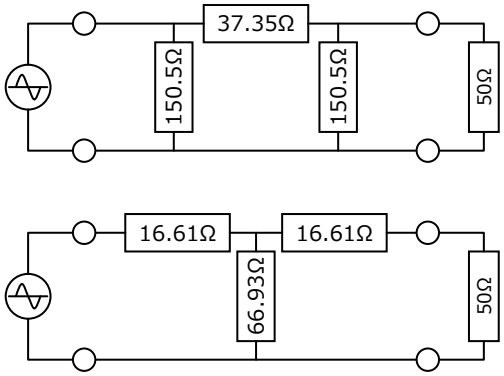

Figure 4. PAI style attenuator and T style attenuator of 50Ω characteristic impedance -6dB attenuation

Figure 4 shows a pie attenuator and a tee attenuator of 6 dB attenuation and 50Ω characteristic impedance using three resistors. Although it is possible to make a attenuator using the chip resistors of each resistance value, the resistance value of the resistor becomes a fraction, and making it difficult to select the resistor. Therefore, the attenuator manufacturer supplies a combined three resistors to a chip as a attenuator. In Figure 4, when input 1V is input, 0.5V appears for output terminated with

characteristic impedance. It's ratio 1/2, so it's attenuation 6 dB.

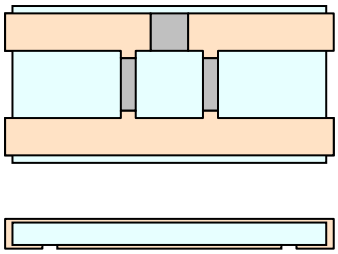

Figure 5. Typical 6dB chip attenuator

4. Allowable power of the attenuator

The attenuator attenuates the input voltage and outputs it. When input voltage is Vi, input power P can be calculated with following equation.

$$P(W) = \frac{Vi^2}{Z}$$

If the input voltage is 100 V applied to an attenuator of 50Ω characteristic impedance, the input power is 200 W.

If the attenuation is 6 dB, 50 V appears to the output, so the termination resistor consumes 50 W. The power consumed inside of the attenuator is 200W - 50W (=150W), so it is 150 W.

If the attenuation is 40dB, if the input power is 200W, the output voltage is 1V and the power consumed by the termination resistor is 20 mW, so most of the input power is consumed inside the attenuator, resulting in a heat generation of 200 W at the attenuator.

Please note that the heat generated inside the attenuator varies depending on the attenuation.

The attenuator has a rated power for the category temperature, but the rated power is defined for the maximum attenuation.

Attenuators such as attenuation 6 dB may be used for impedance matching of internal circuits such as amplifiers, and attenuators such as 30 dB may be used with circulators and isolators.

5. The attenuation and three resistance values of the PAI-style, T-style attenuator

Table 2 shows the attenuations, three resistance values, input-output voltage, input-output power of the PAI-type and T-type attenuator.

PAI-configuration attenuator, impedance 50 Ω

ATT (dB)	IN/OUT ratio	R1(Ω)	R2(Ω)	R3(Ω)	Input Voltage (V)	INP POWER (W)	Output Voltage (V)	OUT POWER (W)
1	1.12	869.55	869.55	5.77	70.71	100	63.02	79.43
2	1.26	436.21	436.21	11.61	70.71	100	56.17	63.10
3	1.41	292.40	292.40	17.61	70.71	100	50.06	50.12
4	1.58	220.97	220.97	23.85	70.71	100	44.62	39.81
5	1.78	178.49	178.49	30.40	70.71	100	39.76	31.62
6	2.00	150.48	150.48	37.35	70.71	100	35.44	25.12
7	2.24	130.73	130.73	44.80	70.71	100	31.59	19.95
8	2.51	116.14	116.14	52.84	70.71	100	28.15	15.85
9	2.82	104.99	104.99	61.59	70.71	100	25.09	12.59
10	3.16	96.25	96.25	71.15	70.71	100	22.36	10.00
15	5.62	71.63	71.63	136.14	70.71	100	12.57	3.16
16	6.31	68.83	68.83	153.78	70.71	100	11.21	2.51
20	10.00	61.11	61.11	247.50	70.71	100	7.07	1.00
30	31.62	53.27	53.27	789.78	70.71	100	2.24	0.10
40	100.00	51.01	51.01	2,499.75	70.71	100	0.71	0.01

T-configuration attenuator, impedance 50 Ω

ATT (dB)	IN/OUT ratio	R1(Ω)	R2(Ω)	R3(Ω)	Input Voltage (V)	INP POWER (W)	Output Voltage (V)	OUT POWER (W)
1	1.12	2.88	2.88	433.34	70.71	100	63.02	79.43
2	1.26	5.73	5.73	215.24	70.71	100	56.17	63.10
3	1.41	8.55	8.55	141.93	70.71	100	50.06	50.12
4	1.58	11.31	11.31	104.83	70.71	100	44.62	39.81
5	1.78	14.01	14.01	82.24	70.71	100	39.76	31.62
6	2.00	16.61	16.61	66.93	70.71	100	35.44	25.12
7	2.24	19.12	19.12	55.80	70.71	100	31.59	19.95
8	2.51	21.53	21.53	47.31	70.71	100	28.15	15.85
9	2.82	23.81	23.81	40.59	70.71	100	25.09	12.59
10	3.16	25.97	25.97	35.14	70.71	100	22.36	10.00
15	5.62	34.90	34.90	18.36	70.71	100	12.57	3.16
16	6.31	36.32	36.32	16.26	70.71	100	11.21	2.51
20	10.00	40.91	40.91	10.10	70.71	100	7.07	1.00
30	31.62	46.93	46.93	3.17	70.71	100	2.24	0.10
40	100.00	49.01	49.01	1.00	70.71	100	0.71	0.01

Table 2. PAI and T style attenuators

6. Inquiry

Please contact to Sales Dept, Nikkohm Co., Ltd.
info@nikkohm.com
+81-(0) 176-53-2105

//