HEWLETT PACKARD

Rectification Effects In PIN Attenuators

Application Note 957-3

Introduction

Attenuation values of PIN diodes are changed by high incident power levels. The effect is most noticeable at intermediate attenuation levels in fast switching diodes. The variation in attenuation may be minimized by proper choice of bias resistance.

An ideal PIN diode acts as a variable resistor controlled by dc current. In attenuation applications, the performance is independent of carrier power level or frequency. The performance of a real PIN diode, however, is limited by both carrier level and frequency because of rectification effects. The effects are more serious at low frequencies because the period is closer to the lifetime of the charge carriers in the diode intrinsic layer. There is sufficient time for these charges to be influenced by the changing rf voltage.

The effects of frequency, power level, bias supply, and type of diode have been investigated for this report. Similar characteristics have been reported for Hewlett-Packard switch modules in AN 932. These effects have also been discussed for UHF attenuation circuits in terms of distortion levels.[1]

Frequency Effect

Attenuation as a function of power level at 2 GHz is shown for three types of diodes in Figures 1, 2, and 3. Corresponding data at 10 GHz is shown in Figures 4, 5, and 6. At the lower frequency, the longer period allows the charges to be influenced by the rf voltage. The attenuation departs from the nominal value at a lower power level and the change is greater. Table I lists this change in attenuation with zero ohms bias resistor at the 1 W level when the bias is set for 3 dB attenuation at 1 mW.

Table I. Attenuation Change at 1 Watt Power Level

Frequency (GHz)	2	10
Diode	**Attenuation Above 3dB (dB)**	
5082-3170	4.4	2.2
5082-3140	5.7	2.6
5082-3141	15.8	7.2

Limiting

At zero bias, the change of attenuation due to injected charge is called limiting. Examination of Table I would lead us to expect better limiting at lower frequencies and with the 3141 type of diode. The data in Table II, showing the increase in insertion loss at 1 W with a zero ohm bias resistor confirms this.

The 3141 type of diode is clearly the superior limiter diode. The 3170 type shows no limiting at 1 W, while the 3140 type is just beginning to limit at the lower frequency.

The sudden change in attenuation at 26 dBm in Figure 3 is a well known phenomenon in limiter diodes. It may happen at different power levels and is often seen above 1 W at 10 GHz. It is an undesirable characteristic because the leakage at this step may exceed the leakage at +50 dBm. This step does not occur in Hewlett-Packard 5082-3071 limiter diodes.

Table II. Limiting at 1 Watt

Frequency (GHz)	2	10
Diode	Loss Increase (dB)	
5082-3170	0	0
5082-3140	0.8	0
5082-3141	10.5	2.3

Bias Current Effect

A glance at Figure 3 will confirm that attenuation setting or bias level has a significant effect on high power behavior. The high level attenuation change is plotted as a function of attenuator setting in Figure 7 to show this more clearly. These curves are similar to curves of distortion level vs. attenuation. [1] The high power effects are most serious at intermediate bias current levels. At high bias currents, a large electric field is necessary in order to have a significant effect on the large number of charge carriers present in the intrinsic layer of the diode. At zero bias current, the rf field must be high in order to inject sufficient carriers to have a significant effect on diode resistance. At intermediate current levels, a reasonable rf field strength is sufficient to significantly effect the charge density.

Load Resistance and Temperature Effects

The 10 dB case in Figure 6 illustrates the compensating effects of temperature and bias resistor value. Since the change of attenuation is caused by rectified current, the most serious effects are seen when the rectified current is largest, with zero bias resistor. The temperature effects are related to the increases in the bias resistor value. Current, and therefore attenuation, rises with temperature with a voltage source, corresponding to the low values of bias resistance. With high values of bias resistance, the power supply acts like a current source. Diode resistance then rises with temperature and attenuation drops. In this mode, the temperature effect can cancel the rectification effect to make the attenuation independent of power level. The required resistance with the 3141 diode is about 5000 ohms for 10 dB attenuation, 500 ohms for 20 dB, and 50,000 ohms for 3 dB.

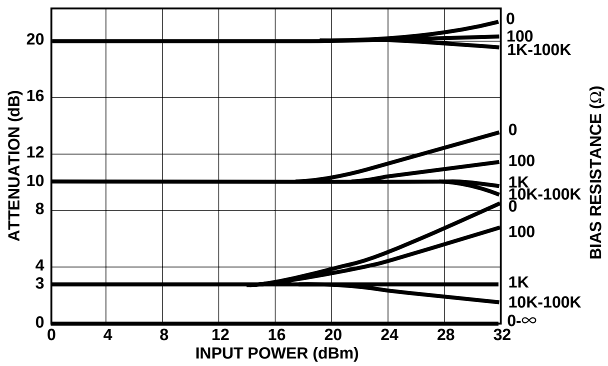

Figure 1. Attenuation at 2 GHz vs. Input Power with Bias Resistance as a Parameter. 5082-3170 at 0 dB, 3 dB, 10 dB and 20 dB.

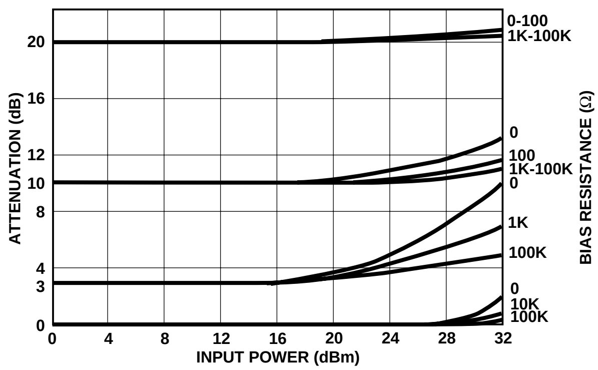

Figure 2. Attenuation at 2 GHz vs. Input Power with Bias Resistance as a Parameter. 5082-3140 at 0 dB, 3 dB, 10 dB and 20 dB.

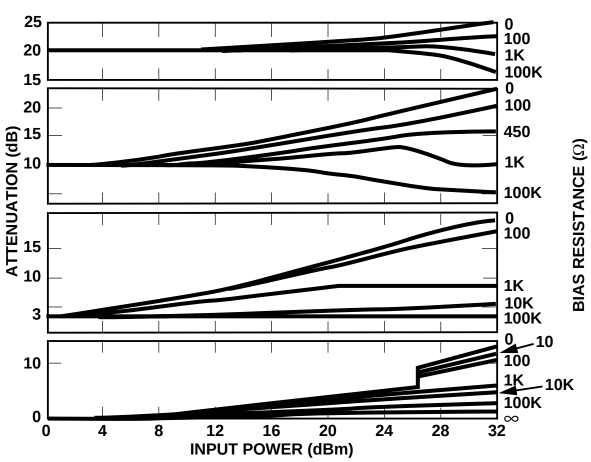

Figure 3. Attenuation at 2 GHz vs. Input Power with Bias Resistance as a Parameter. 5082-3141 at 0 dB, 3 dB, 10 dB and 20 dB.

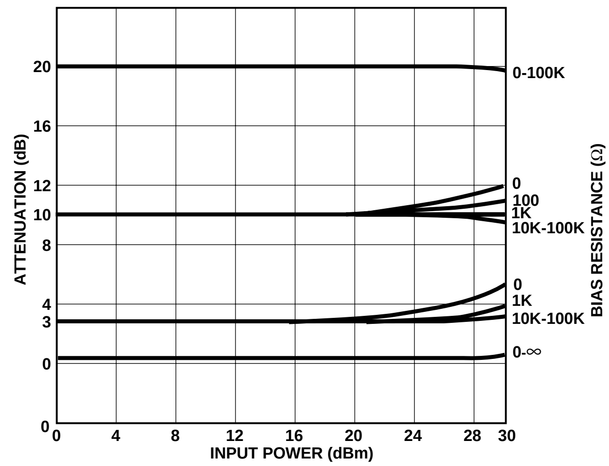

Figure 4. Attenuation at 10 GHz vs. Input Power with Bias Resistance as a Parameter. 5082-3170 at 0 dB, 3 dB, 10 dB and 20 dB.

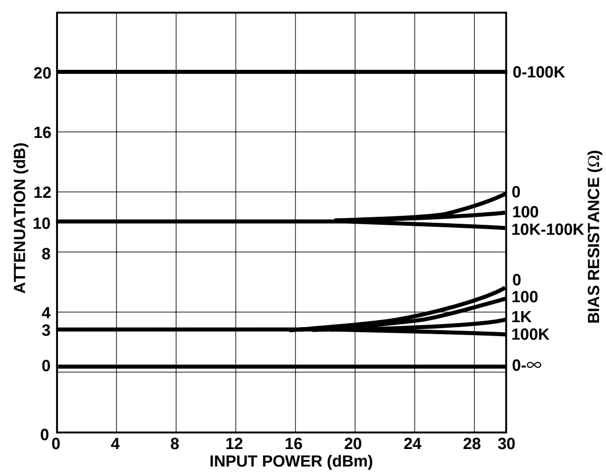

Figure 5. Attenuation at 10 GHz vs. Input Power with Bias Resistance as a Parameter. 5082-3140 at 0 dB, 3 dB, 10 dB and 20 dB.

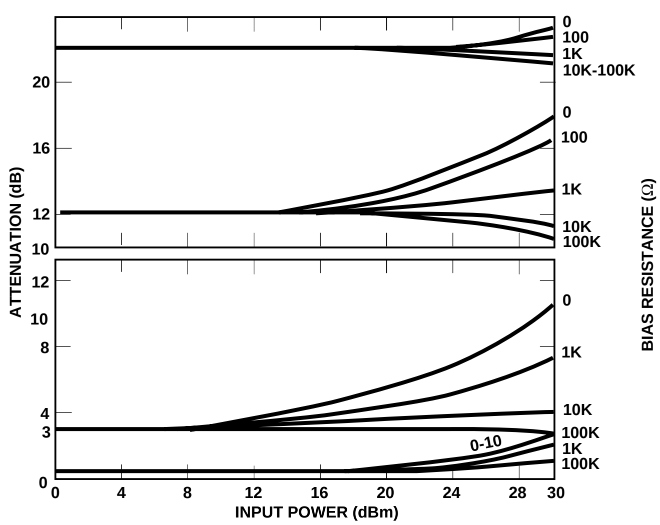

Figure 6. Attenuation at 10 GHz vs. Input Power with Bias Resistance as a Parameter. 5082-3141 at 0 dB, 3 dB, 10 dB and 20 dB.

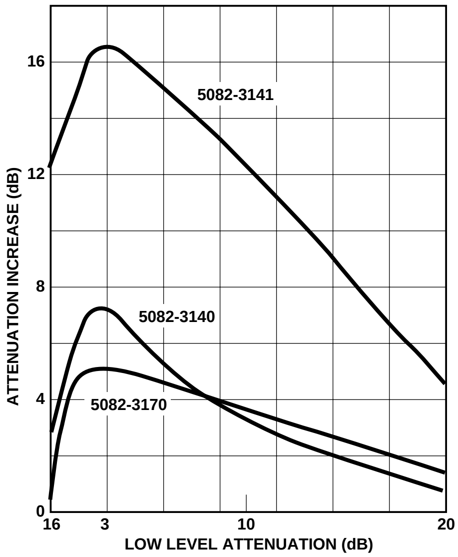

Figure 7. Effect of +32 dBm Power Level on Shunt PIN Diode Attenuators at 2 GHz.

The diode characteristics plotted in the figures are independent of package type. Table III lists other Hewlett-Packard standard parts which are made from the same basic chip as the 5082-3170, 5082-3140, and 5082-3141.

Table III. HP Diodes Exhibiting Similar Characteristics

5082-3170	5082-3140	5082-3141
5082-0030	5082-0012	5082-0001
5082-3301	5082-3000	5082-3010
5082-3302	5082-3001	5082-3041
5082-3303	5082-3002	5082-3042
5082-3304	5082-3005	5082-3043
5082-3309	5082-3039	5082-3045
5082-3340	5082-3040	5082-3071
	5082-3077	5082-3141
	5082-3101	5082-3258
	5082-3102	5082-3305
	5082-3201	5082-3306
	5082-3202	
	5082-3259	

References

1. Jack Lepoff, "A New PIN Diode for UHF-VHF Applications", Trans. IEEE, Vol. BTR-17, No. 1, Feb. 1971, pp. 10-15.

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Data Subject to Change

Printed in U.S.A. 5952-8429 (10/75)