Although Schottky barrier diodes are less sensitive to temperature changes than point-contact diodes,[1] the effect on detector voltage sensitivity may be significant. Performance improves at lower temperatures in a predictable manner. In fact, a second diode can be used in a compensating circuit[2] to cancel out the temperature effects.

Typical behavior of voltage sensitivity vs. temperature is shown in Figure 1. This spread of values (approximately 1 dB) was obtained from ten Avago Technologies’ 5082-2750 Schottky detector diodes chosen at random from two different lots.

The temperature dependence of current sensitivity was studied by Cowley and Sorensen,[3] but the analysis was not extended to voltage sensitivity. For the ideal diode with infinite cutoff frequency (zero series resistance and/or zero junction capacitance), there is no temperature effect on voltage sensitivity. The inverse temperature behavior of current sensitivity is balanced by the direct temperature variation of the diode barrier resistance. That is, for current sensitivity:

$$\beta = \frac{q}{2 nkT} = \frac{5400}{T}$$  \hspace{1cm} (1)

and for diode junction resistance:

$$R_j = \frac{nkT}{qI} = \frac{T}{11I}$$  \hspace{1cm} (2)

In these equations, $T$ is temperature in degrees Kelvin, $I$ is bias current in milliamperes and $n$, $q$, and $k$ are constants.[3] When the load resistance is much greater than diode resistance, the voltage sensitivity, $\gamma_o$, is the product of current sensitivity and junction resistance and is independent of temperature:

$$\gamma_o = \beta R_j = \frac{490}{I}$$  \hspace{1cm} (3)

In practical cases, however, the voltage sensitivity is reduced by the presence of both junction capacitance and series resistance, i.e.:

$$\gamma = \frac{\gamma_o}{1 + 4\pi^2 f^2 C_j^2 R_s R_j}$$  \hspace{1cm} (4)

The temperature dependence shows up in the $R_j$ term (equation 2). Using typical values of $I = .02 mA$, $R_s = 25$ ohms, $C_j = 0.1$ pF, and $f = 10$ GHz, the effect of temperature on voltage sensitivity is:

$$\gamma = \frac{\gamma_o}{1 + .0045T}$$  \hspace{1cm} (5)
For a typical voltage sensitivity of 6.5 mV/μW at T = 293°K, γ₀ = 15.1 mV/μW. Figure 2 shows this theoretical curve in excellent agreement with experimental data from a typical diode.

However, when f = 1 GHz, equation (4) predicts a response nearly independent of temperature:

\[
\gamma = \frac{\gamma_0}{1 + 4.5T \times 10^{-5}}
\]  

(6)

Measurements at this frequency are not in good agreement with this prediction. Figure 3 shows considerable improvement in performance over temperature, but there is still a 25% variation. A theoretical model of the temperature behavior of a Schottky detector is in excellent agreement with 10 GHz measurements. Further refinement of the theory is necessary to extend the model to lower frequencies.

References