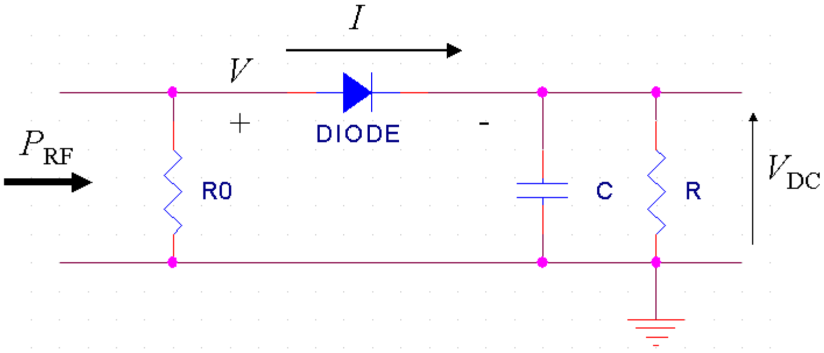
WORKING PRINCIPLE OF A DIODE POWER METER

A power meter should include a matching network, the non-linear element (diode), an output low-pass filter and the final load. We can consider the simplified circuit shown in figure, with an input matching impedance R_0= 50 Ω. The diode equation is:

$$I = I_s\,[\exp(V/nV_T)-1], \tag{1}$$

where $V_T = kT/e \cong 25$ mV at ambient temperature, k is the Boltzmann constant, n a number between 1 and 2, T the absolute temperature value in K and I_s the inverse saturation current.



In order to describe the diode behavior for low voltages, we can develop in series the exponential:

$$I = I_s\left(\frac{V}{nV_T} + \frac{V^2}{2(nV_T)^2} + \frac{V^3}{3!(nV_T)^3} + \ldots\right) \tag{2}$$

If we consider an input sinusoidal voltage V, due to the input power R_0, with $V = V_{RF}\sin(\omega t)$ and thus $P_{RF} = \frac{V_{RF}^2}{2R_0}$ (at radiofrequency, the diode cathode is grounded by the capacitor C, therefore the whole RF voltage falls on the diode).

For very-low voltages $V \ll V_T$ we can stop the series to the second term, neglecting the contribution of the higher-order terms. In this approximation, the DC component of the current, equal to the average value of I is given by:

$$I_{DC} = \langle I \rangle = I_s\frac{\langle V^2 \rangle}{2(nV_T)^2} = I_s\frac{V_{RF}^2\langle \sin^2(\omega t)\rangle}{2(nV_T)^2} = I_s\frac{V_{RF}^2}{4(nV_T)^2} \tag{3}$$

The differential resistance R_D of the diode is given by:

$$\frac{1}{R_D} = \left.\frac{\partial I}{\partial V}\right|_{I=0} = \frac{I_s}{nV_T} \tag{4}$$

For a RF diode, the saturation current has value close to 10 μA, hence its differential resistance is equal to some kΩ: being $R_D \gg R_0$, the diode presence does not compromise the input line matching. The current I_{DC} falls on the diode differential resistance R_D in parallel with the load R, whose value is >> R_D. In this way we obtain an output DC voltage equal to:

$$V_{DC} = I_{DC}R_D = R_D I_s\frac{V_{RF}^2}{4(nV_T)^2} = \frac{V_{RF}^2}{4nV_T} = \frac{R_0}{2nV_T}P_{RF} \tag{5}$$

By substituting the values we get a sensitivity between 0.5 mV/μW and 1 mV/μW.

If we consider a noise floor equal to 100 nV, for example, the minimum RF input power is about -70 dBm, which is precisely the noise background of this type of detectors.

This discussion does not consider the non-ideality of the circuit and of the diode itself, and is mathematically valid only for input powers below -20 dBm, power level corresponding to the condition $V < V_T$.