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LINEARIZATION OF DIODE DETECTOR CHARACTERISTICS

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Abstract

A novel mathematical model is introduced for determining the RF input power as a function of Schottky diode detector output voltage. It has been used in Ka-band. The results show that it is well suited for linearization of detector characteristics over large input power range.

Introduction

The aim of this investigation was to linearize the diode detector characteristics and enable diodes as power detector in six-port network analyzer over large dynamic range. The deviation from square law for Silicon Schottky diode remains under 0.05 dB below -20dBm power level and reaches a 0.2 dB at -16 dBm. The DC output voltage of the detector at -20dBm power level is only about 2.5 mV (1). If such detectors are used in a six-port system, more errors will be resulted. The bolometer with true square law can be used, but a large amount of RF input power is required. Sometimes, it is difficult to get high power level, especially at millimeter-wave band. So, it is desired to linearize the diode detector characteristics.

A mathematical model was developed ten years ago(2). However, it is not suited for large input power range. When the output voltage is reduced to zero, the deviation from square law, according to the model, tends to infinite.

Novel Model

A novel mathematical model has been developed by autuors as follows

$$P=KV(10^{\frac{1}{10}\sum_{i=1}^{N} a_i x^i}) \qquad (1)$$

where P is the RF input power, V is the output voltage, K and a_i are constants, x is a function of V

$$x=\ln(V/q+1) \qquad (2)$$

where q is a scalar factor chosen so that x is positive and has a maximum value of about 0.5. Equations (1) and (2) can be used over large dynamic range, because x is a logarithmic form of V. The deviation from square law is

$$E=\sum_{i=1}^{N} a_i x^i \quad (dB) \tag{3}$$

As $V \to 0$, then $x \to 0$ and $E \to 0$, so the model is consistent with the square law approximation of diode detector with lower input power level.

Simulation

From equations (1)—(3), we can obtain

$$L_l = 10\, Log_{10}(V_l/V_{l+1}) + E_l - E_{l+1} \tag{4}$$

$$L_k = 10\, Log_{10}(V_k/V_{k+1}) + E_k - E_{k+1} \tag{5}$$

If $L_l = L_k$, then

$$10\, Log_{10}(V_l/V_{l+1} \cdot V_{k+1}/V_k) = \sum_{i=1}^{N} a_i (x_l^i - x_{l+1}^i - x_k^i + x_{k+1}^i) \tag{6}$$

Repeating the measurement of V_l and V_{l+1} at different input power levels with a two-position attenuator, a number of equations like (6) can be obtained. The least square method has been used to solve these equations for the constants a_i in the model. Note that the L_l needn't to be known accurately in finding a_i. The setup for measuring the diode detector characteristics is shown in Figure 1. The attenuator A_1 is used to change the input power level by step of about 1 dB and A_2 is a precision attenuator which is used as a two-position attenuator. The L_l is about 6 dB.

Measurement of Deviation

After above linearization procedure we can use the setup shown in Figure 2 to measure the deviation from square law of the diode detector with the new model. The precision power meter has an ideal square law. It is always used in the 0—-10dBm range by adjusting attenuators A_1 and A_2.

The indicated power level of diode detector P_{di} can be written as

$$P_{di} = P_{dio}(1+\delta P_{di}) \tag{7}$$

where P_{dio} is assumed to be the power level measured by the diode detector with ideal square law, and δP_{di} is the deviation at P_{di}. Let

$$\Delta D_i = 10\, Log_{10}(P_{di}/P_{d1}) - 10\, Log_{10}(P_{Pi}/P_{P1}) \tag{8}$$

where P_{Pi} is the power level measured by the precision power meter. Thus

$$\Delta D_i \approx 4.34\,(\delta P_{di} - \delta P_{d1}) \tag{9}$$

where it has been assumed that the ideal detector have the following relation over the considered range

$$\sum_{i=1}^{N} \delta P_{di} = 0$$

So from equation (9) we can obtain

$$\delta P_{di} = \frac{1}{4.34}\left(\Delta D_i - \frac{1}{N}\sum_{j=2}^{N} \Delta D_j\right) \tag{10}$$

Some Results and Discussion

Typical results obtained at Ka--band are listed in Table 1. The four broadband diode detectors and DC amplifier were made in our laboratory for Ka-band six-port reflectometer. One of the results is shown in Figure 3 and 4. While the input power level is about -40 dBm, the DC output voltage is only about 30μV. In that case the effects of noise and drift of the amplifier cannot be neglected. So the Ripple of the deviation at P_{in} near -40dBm in Figure 4 is apperantly much larger. In our experiments the maximum RF input power level of about 0 dBm is limited by the dynamic range of the DC amplifier. If it would be replaced by a chopper stablized amplifier and a precision digital multimeter, the available dynamic range of the model developed in this paper is hopeful to be enlarged.

References

(1) R. A. Fong-Tom and H. M. cronson, "Diode Detector Characteristics for 94GHz Six-Port Apllications", 1982 IEEE MTT-S Digest, p.319

(2) C. A. Hoer et al, " Measuring and Minimizing Diode Detector Nonlinearity", IEEE Trans. IM-25, No. 4, pp.324-329, Dec. 1976

Table 1

Maximum deviation from square law over 0—-35 dBm (%)

Det.	30GHz	33GHz	35GHz	38GHz
1#	.63	.41	.12	.31
2#	.25	.58	.50	.45
3#	.28	.66	.11	.37
4#	.23	.32	.59	.64

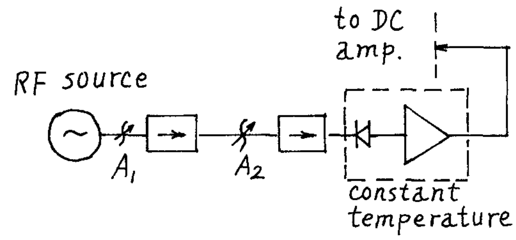

Fig.1 setup for simulation

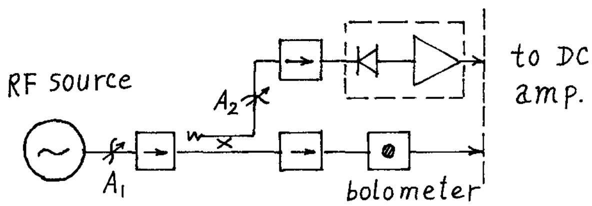

Fig.2 setup for measuring deviation

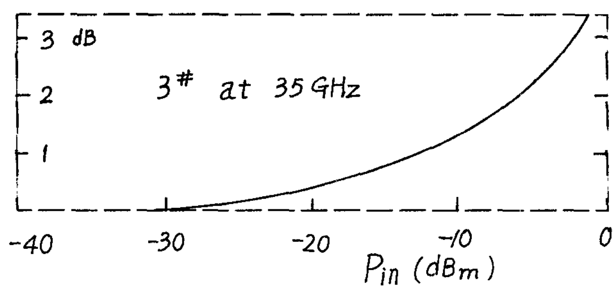

Fig.3 deviation without modeling

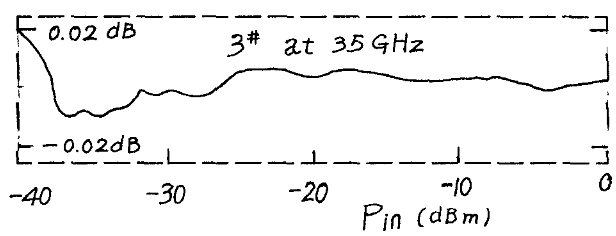

Fig.4 deviation with modeling