CHAPTER 4

LARGE SIGNAL S-PARAMETERS

4.0 Introduction

Small-signal S-parameter characterization of transistor is well established. As mentioned in chapter 3, the quasi-large-signal approach is the most accurate way to measure the large-signal S-parameters for transistors, especially S_{12} S_{22}. Attempts to obtain accurate large-signal S-parameters for transistors using the direct extension of small-signal measurements methods have been of limited success, especially in cases where the non-linearity is severe such as in class-C. Of course one of the main advantages of the direct extension of the small-signal measurement method is its simplicity.

The objective of this chapter is to study the design accuracy of class-A power amplifier based on small-signal S-parameters.

4.1 Large-Signal S-Parameters Measurement

The MESFET transistor used in this work is the ATF-46100, manufactured by Hewlett Packard (HP). The ATF-46100 is a gallium arsenide Schottky-barrier-gate field effect transistor designed for medium power, and linear amplification. The simulation shown in this work is obtained using the ATF-46100's EEFET3 nonlinear model [HP Advance Design System Manual].

4.1.1 Large-Signal S-parameters for Class A

As mentioned earlier, the class-A amplifier has a higher linearity than the other classes of amplifiers. This makes the design of the large signal class-A amplifier possible using the small-signal S-parameters. However, for class-AB, B, or C, the small-signal S-parameters are not suitable for design purposes. The DC Simulation component of the HP-ADS is used to determine the proper biasing point. Figure.4.1 shows the dc simulation setup. The curve tracer for the ATF-46100 as shown in Fig.4.2 is obtained by varying V_{GS} and V_{DS}.

From Fig.4.2, for the ATF-46100 to be in Class-A, V_{GS} and V_{DS} are chosen to be *–3.5 V* and *6 V*, respectively. The next step is to find the dependence of the S-parameters on the input power. Figure.4.3 shows the S-parameters simulation setup for the ATF-46100. Figure.4.4 shows that over wide range of power, with exception of the magnitudes of S_{21} and S_{22}, the S-parameters are not a strong function of the applied power. Also, the large-signal S-parameters start deviating from the small-signal S-parameters when the applied power exceeded a certain level ($P_{in}=10$ *dBm for 50W load*).

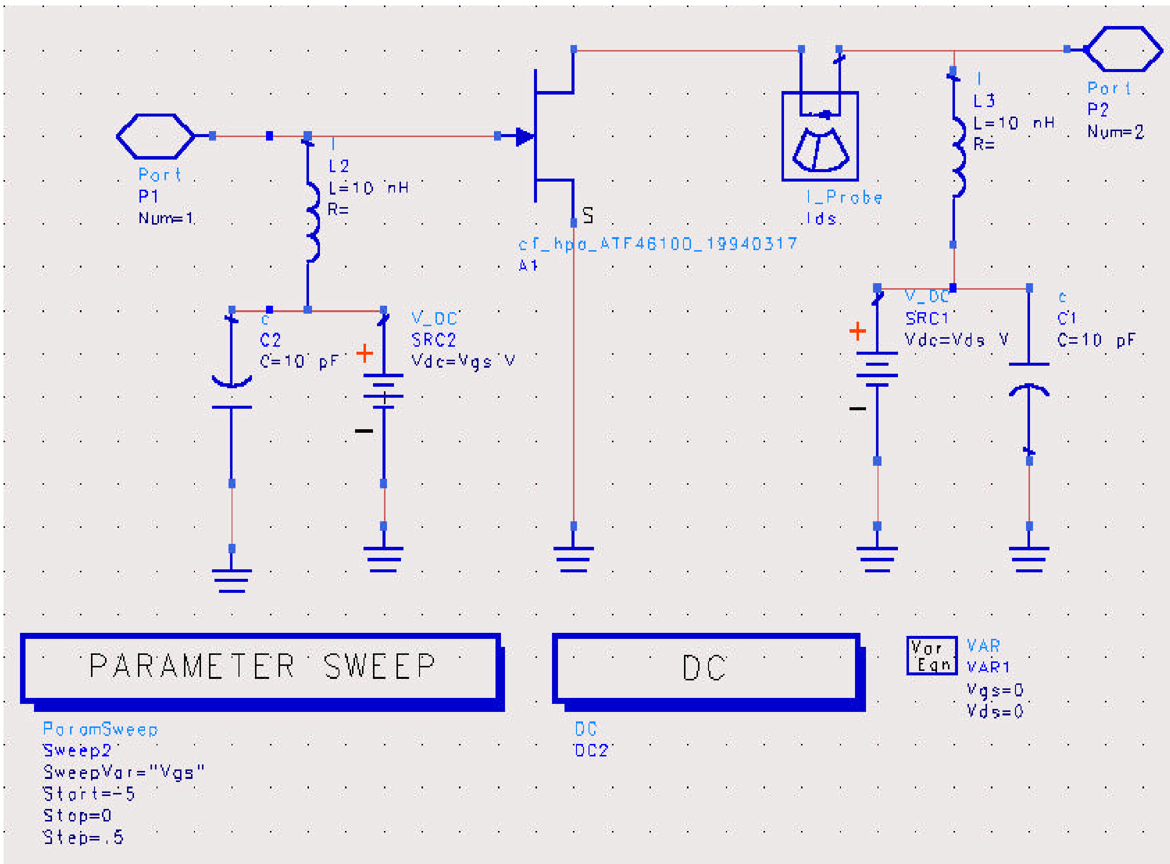

Figure 4.1 ATF-46100 DC simulation setup.

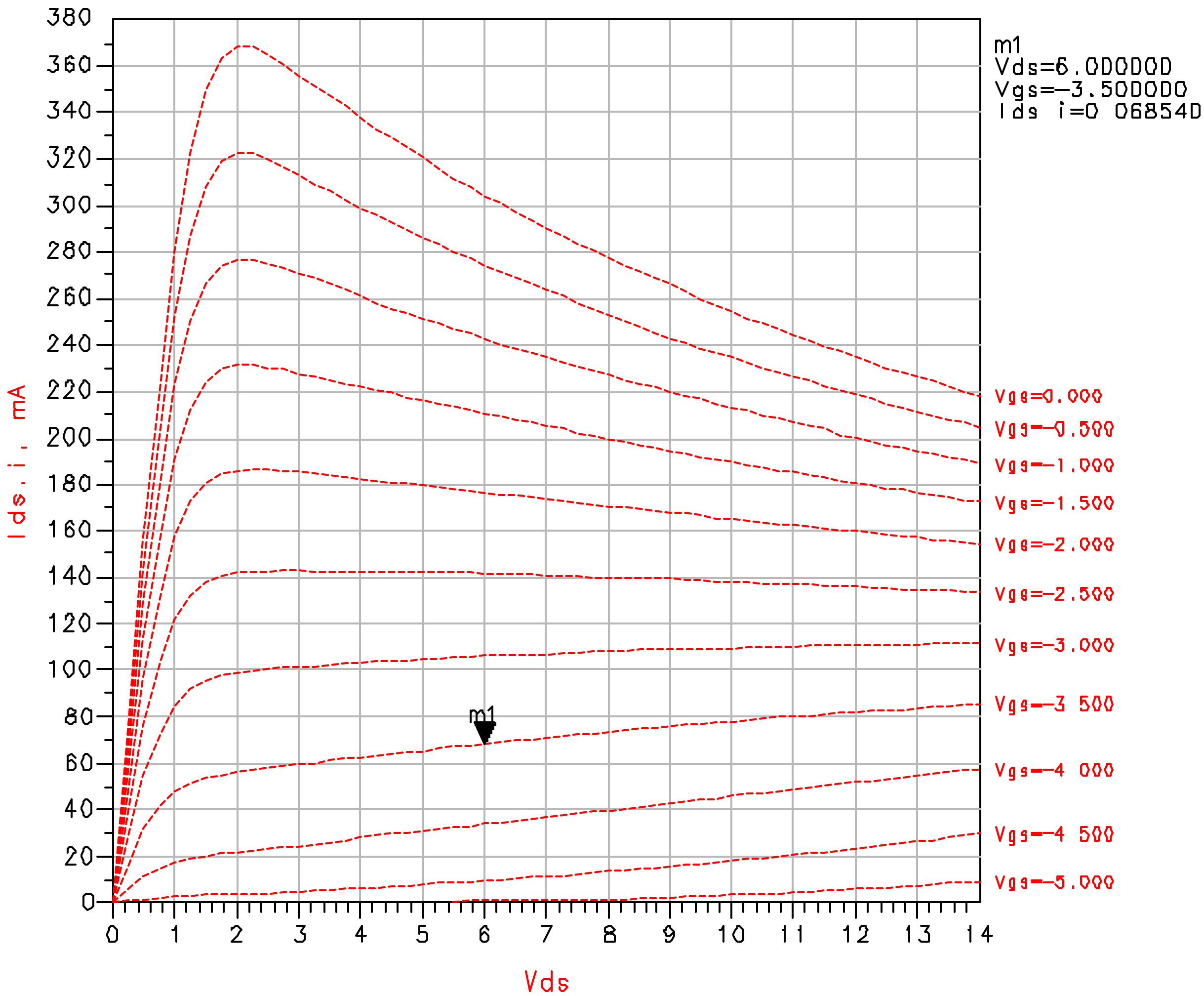

Figure 4.2 DC curve tracer for the ATF-46100

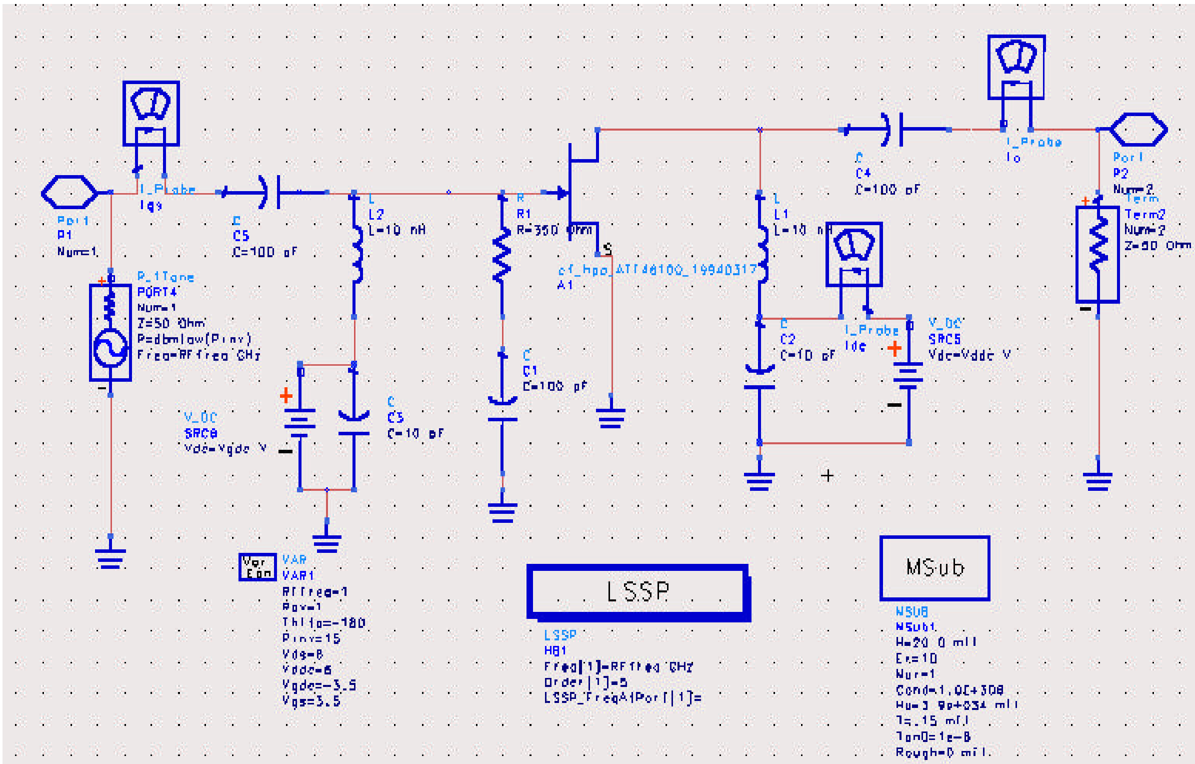

Figure 4.3 S-parameters simulation setup for the ATF-46100.

For every load value there is an input power level above, which the large signal S-parameters will start to deviate way from the small signal S-parameters. The power gain can be used as an indicator for the linearity and, in consequently, the accuracy of the design using the small-signal S-parameters at the desired input power level. Figure.4.5 shows the simulation setup used to calculate the power gain of the transistor ATF-46100 versus the input power for different load values. One dB, and 0.2 dB compression points for the gain at different input power levels are shown in figures.4.6, and 4.7 respectively.

Before the small-signal S-parameter technique can be used in designing a large signal amplifier, its limitation needs to be known. The accuracy required for the design can be used to find this limitation.

Knowing the acceptable gain compression value (XdB) is the first step in the design. The device data sheet showing the XdB compression gain versus the input power is needed. One important need to be noticed is that the XdB compression gain varies with the biasing point. Therefore, the data sheet should include the XdB compression gain at the desired input power and biasing point. The next step is to find the proper load and source impedance. This can be done based on the operating power gain G_P procedure.

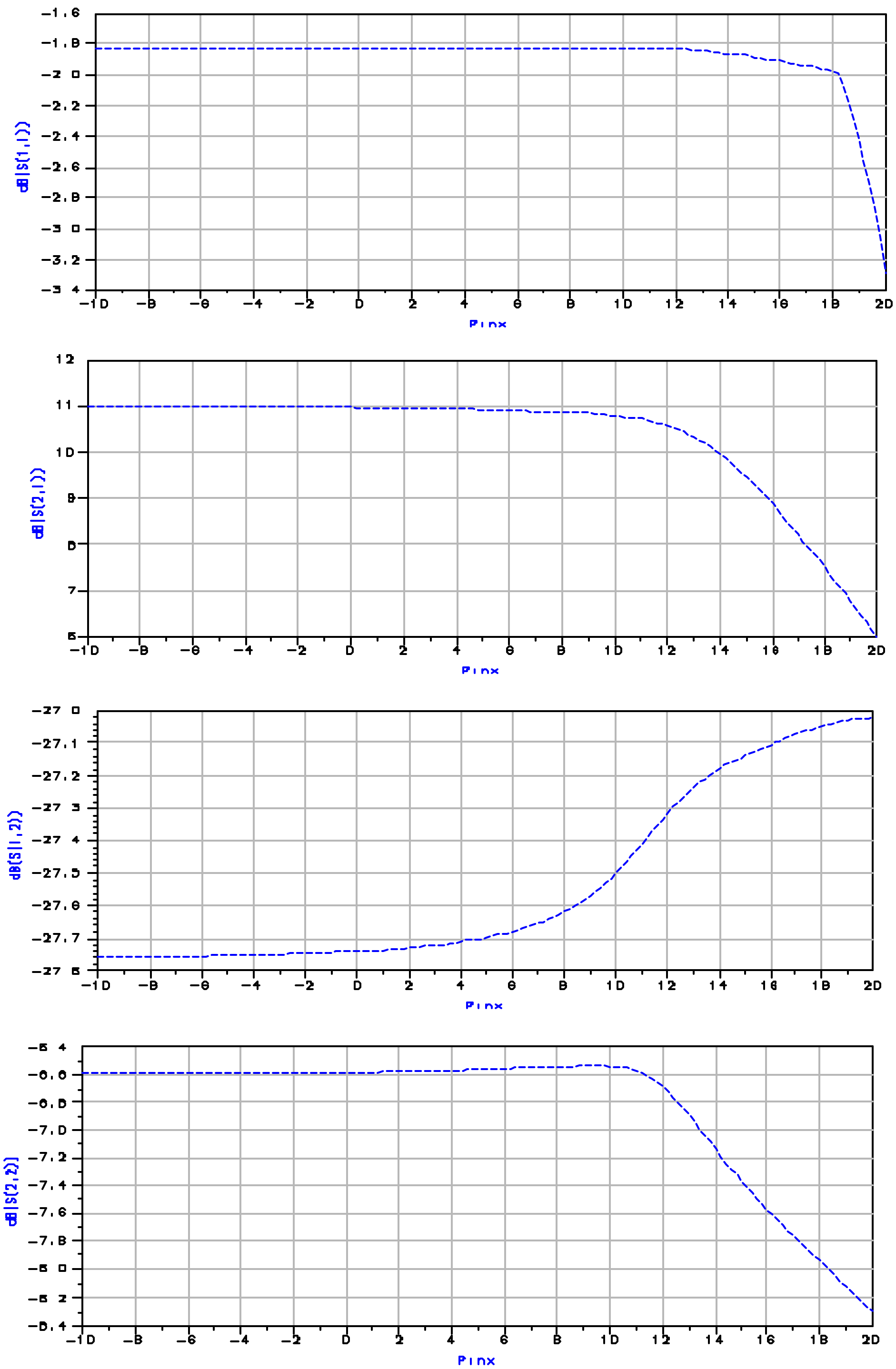

Figure 4.4 (a) S-parameters in dB vs. the input power.

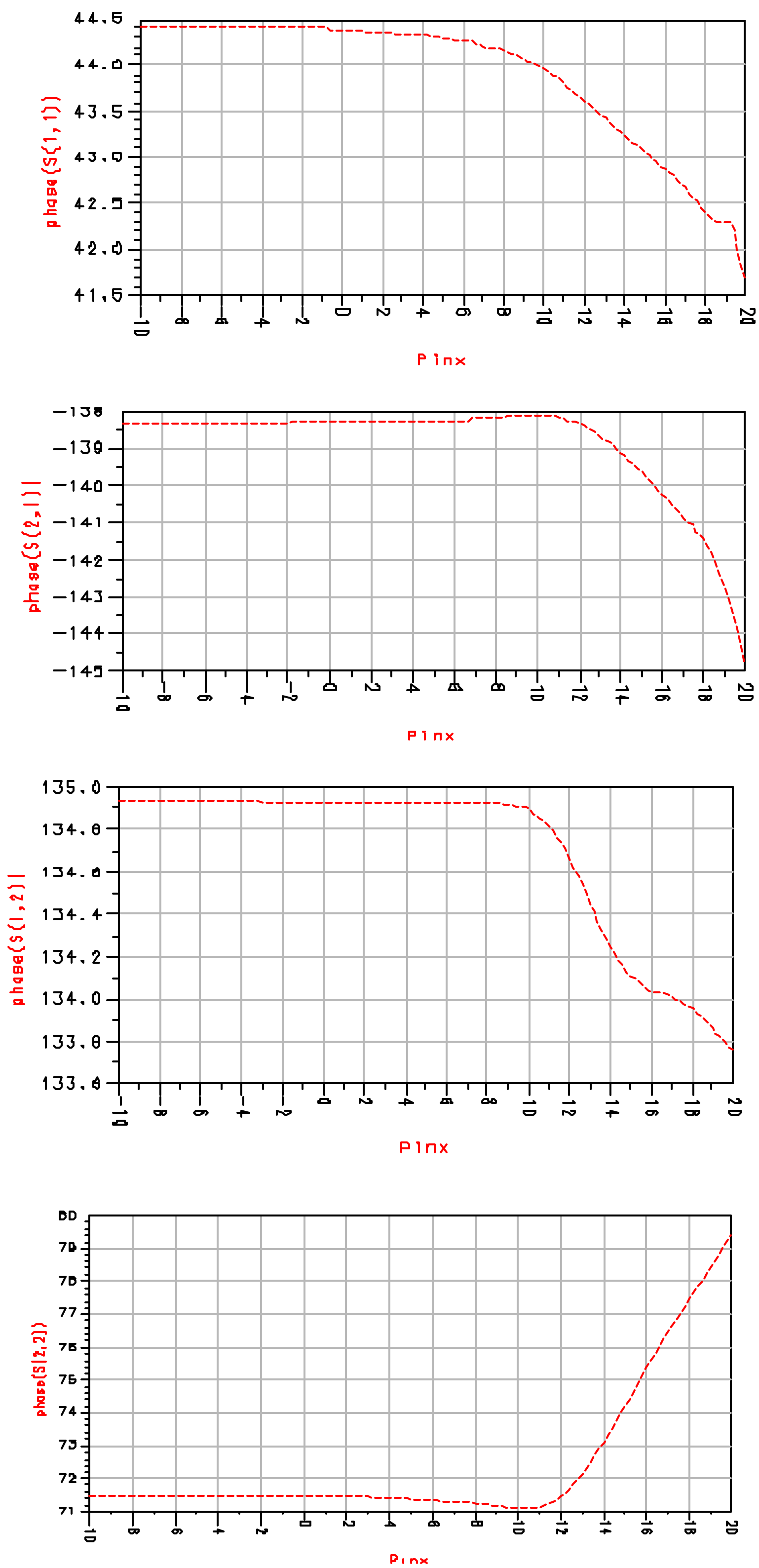

Figure 4.4 (b) Angle of S-parameters in degree vs. the input power.

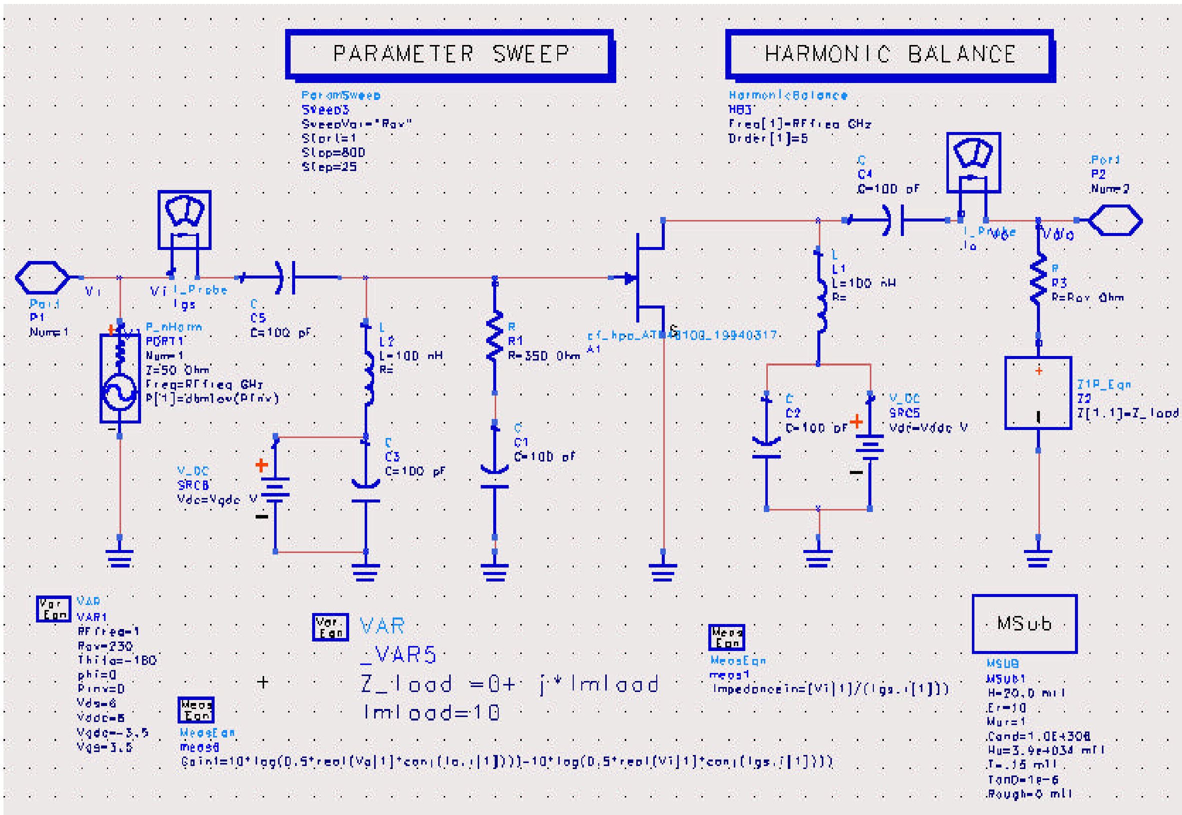

Figure 4.5 Harmonic balance simulation setup for the gain.

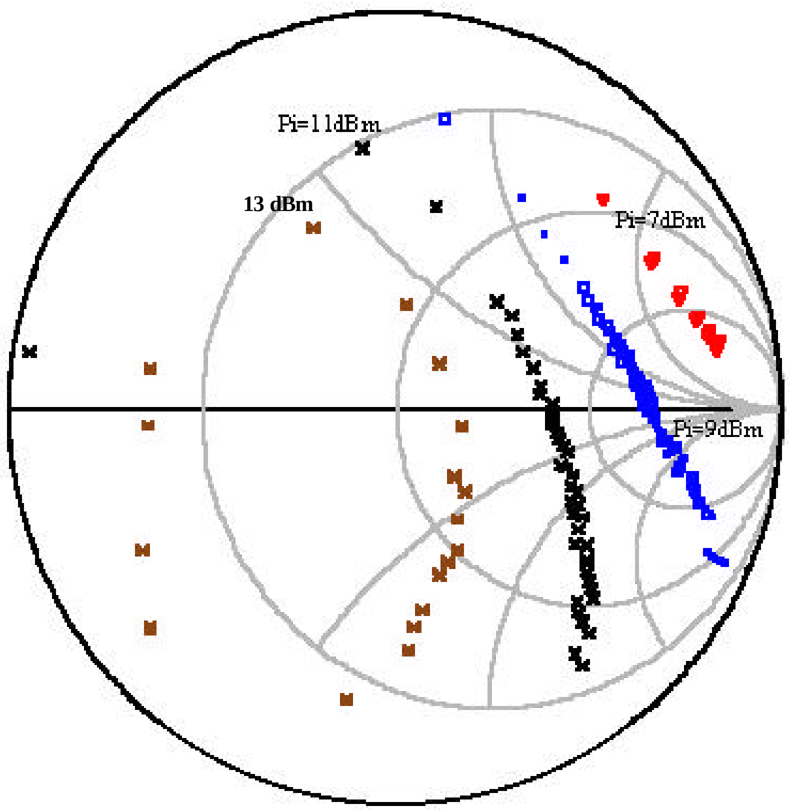

Figure 4.6 1dB Compression point Vs. input power.

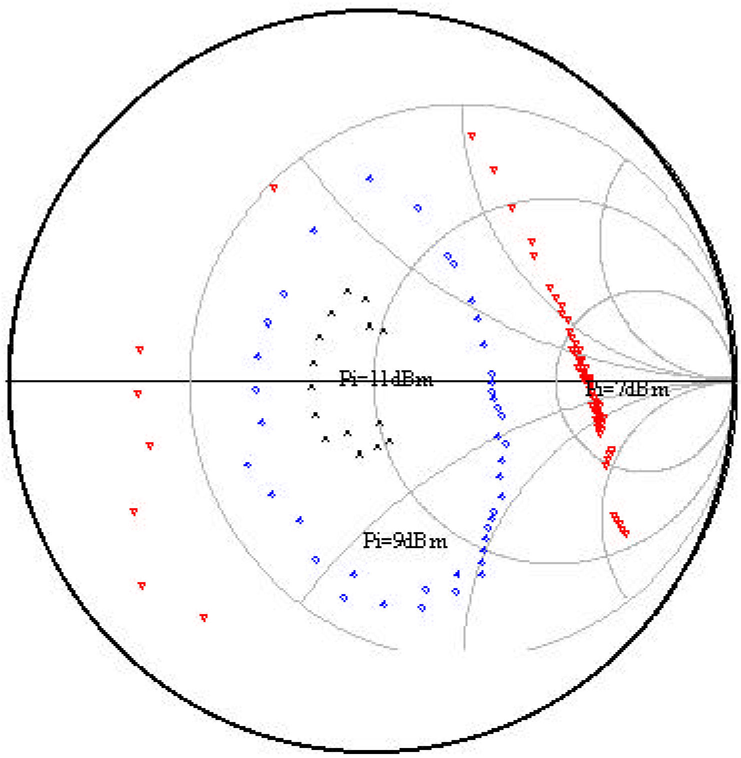

Figure 4.7 0.2 dB Compression point vs.input power.

The operating power gain G_P is defined as the ratio of the power delivered to the load to the amplifier input power. G_P can be defined in terms of the S-parameters, as shown in Equation 4.1 [G. Gonzalez, 1984].

$$G_P = \frac{|S_{21}|^2 \cdot \left(1 - |\Gamma_L|^2\right)}{\left(1 - \left|\frac{S_{11} - \Delta\Gamma_L}{1 - S_{22} \cdot \Gamma_L}\right|^2\right) \cdot |1 - S_{22} \cdot \Gamma_L|^2} \quad . \tag{4.1}$$

Different values of G_P can be obtained; every value forms a circle in the Smith chart. Equations 4.2 and 4.3 give the radius and center of the constant operating power gain circles, respectively [G. Gonzalez, 1984]:

$$R = \frac{[1 - 2K \cdot |S_{12} \cdot S_{21}| \cdot g_P + |S_{12} \cdot S_{21}|^2 \cdot g_P{}^2]^{1/2}}{\left|1 + g_P \cdot (|S_{22}|^2 - |\Delta|^2)\right|} \tag{4.2}$$

$$C = \frac{g_P \cdot C_2^*}{\left|1 + g_P \cdot (|S_{22}|^2 - |\Delta|^2)\right|} \tag{4.3}$$

Where,

$$g_P = \frac{\left(1 - |\Gamma_L|^2\right)}{|1 - S_{22} \cdot \Gamma_L|^2 - |S_{11} - \Delta\Gamma_L|^2} \tag{4.4}$$

$$C_2 = S_{22} - \Delta \cdot S_{11}{}^* \quad . \tag{4.5}$$

For a specific value of G_P, the operating gain circle can be drawn using Equations 4.2 and 4.3. The proper load is obtained using the data sheet and G_P circle. The maximum output power can be obtained with the conjugate matching at the input.

As mentioned earlier, the XdB compression gain varies with the biasing point. Although the XdB compression gain data sheet allows the use of small-signal S-parameters to the limit, the XdB compression gain information needs to be provided at different biasing points. An interesting relation between the XdB compression gain curve and the drain biasing voltage (V_{DS}) can be noticed by comparing Figures.4.6 and 4.7, where V_{DS} is 6V, with Fig.4.8, where V_{DS} is 7V. Varying V_{DS} affects the XdB compression gain of the amplifier with any load by the same amount. This observation will reduce the information needed. Therefore, knowing the XdB compression gain at a certain value of V_{DS}, and the effect of the change of V_{DS} on the XdB compression gain with 50 Ω load is enough to obtain the XdB compression gain at other V_{DS} values.

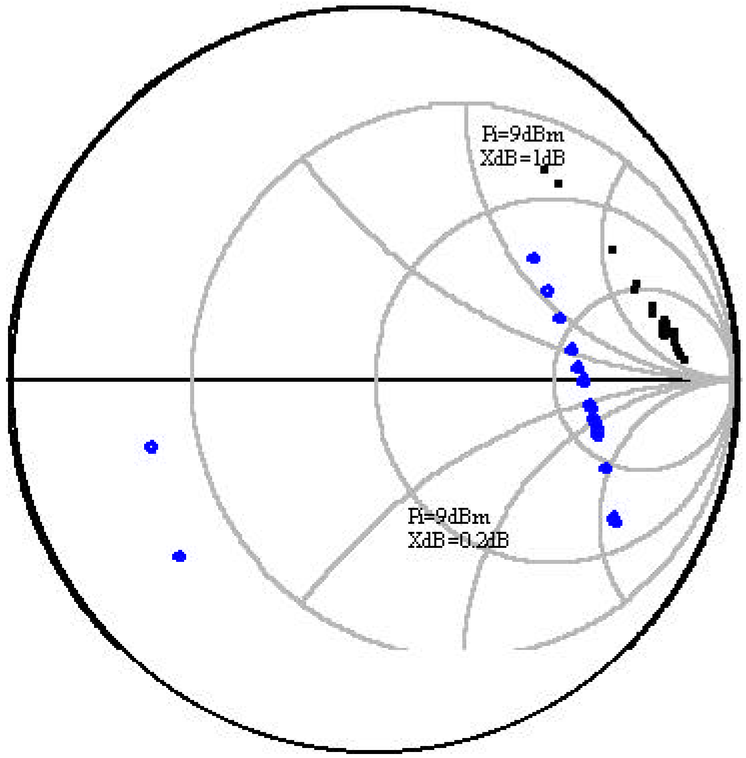

Figure 4.8 XdB Compression Gain, V_{DS}=7V.