The Design of 2.4GHz Bipolar Oscillator by Using the Method of Negative Resistance
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Introduction

In this application note, the design on a 2.4GHz bipolar oscillator by the method of negative resistance will be used. In the design, a circuit simulator Advanced Design System (ADS) from Agilent Technologies will be used and it will be used to evaluate the performance of the designed oscillator at the end of the design.

Theory

In the negative resistance oscillator design, the negative resistors can be realized easily by a three terminals active device with proper feedback. This negative resistor is used to cancel out the lost from the resonator.
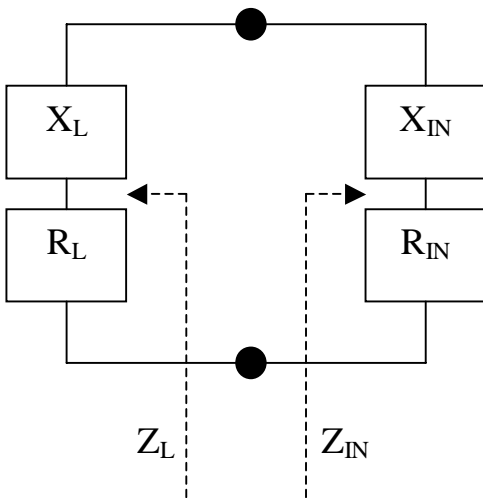

Fig.1   Negative resistance oscillator

The figure above (Fig. 1) shows a typical negative resistance oscillator. First, it is necessary to make sure the overall circuit to be unstable such that:

$$R_{IN} + R_L < 0 \quad \dots\dots\dots\dots(1)$$

When a stable oscillation occurs, the following conditions must be satisfied:

$$R_{IN} + R_L = 0 \quad \dots\dots\dots\dots(2)$$
$$X_{IN} + X_L = 0 \quad \dots\dots\dots\dots(3)$$

Base on the theory above, a negative resistance will be designed and simulated in ADS to satisfy equation (1) and a resonator will be designed and simulated in ADS to satisfy equation (2) and (3). Finally, the combined circuit will be simulated in ADS by the method of harmonic balance to see the overall performance the oscillator.

Simulator

There are many different simulators provided in ADS. In this oscillator design, only some are needed and they will be introduced here.

a. DC simulator

The DC simulator (Fig. 2) is used to simulate the dc performance of the circuit. It is used to design the dc biasing circuit in this design.
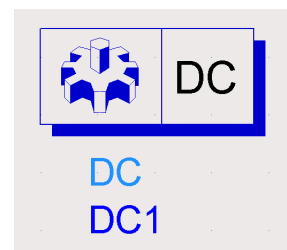

Fig. 2   DC simulator

b. S-parameter (S_param) simulator

The S_param simulator is used to find the circuit parameters such as s-, z- and y-parameters. The start and stop frequency of the wanted parameter is required by the simulator (Fig. 3). Besides, a circuit termination should be added in the circuit schematic as the measurement port of the circuit. It is used to find the input impedance of the active device in the negative resistance design and used to check the three oscillation condition equations in the resonator design.
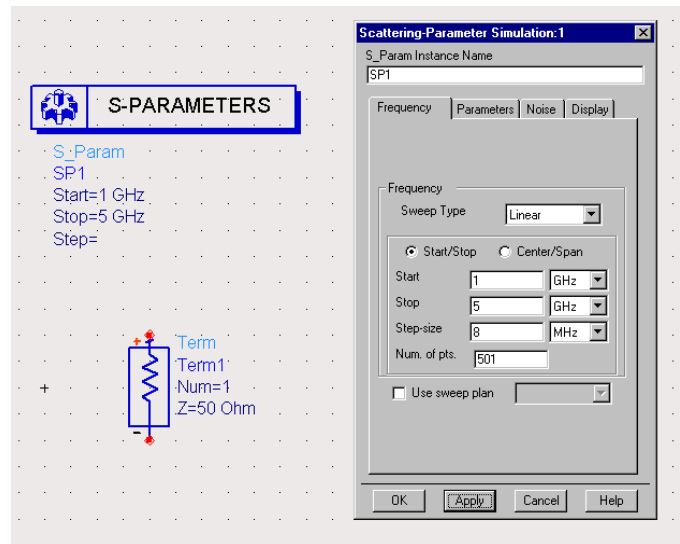

Fig. 3   S_param simulator

c. Harmonic balance (HB) simulator

The HB simulator is used to simulate the performance of the oscillator. In this simulator, the expected fundamental frequency is required. Besides, an osc-port component is added in the circuit schematic. The osc-port should be placed such that it separates the negative-resistance portion of the oscillator from the resonator portion. The arrow should point in the direction of the negative resistance. This simulator is used in the final evaluation of the oscillation circuit.
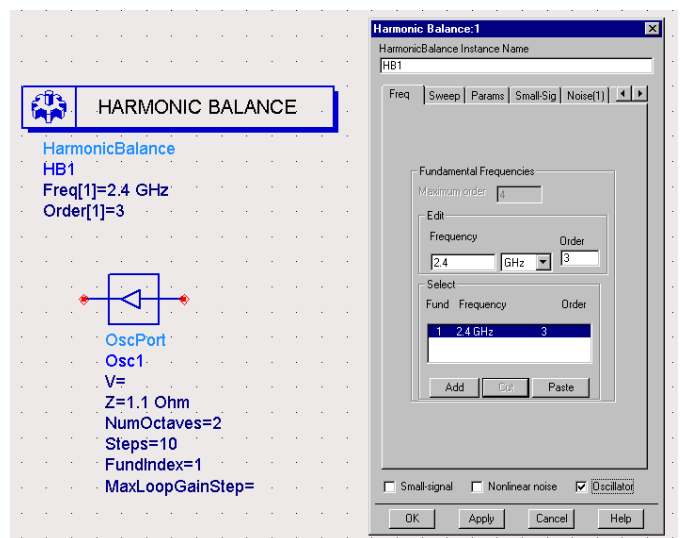

Fig. 4 Harmonic balance simulator

Circuit Simulation and Result

a. Biasing circuit

Before we start the design, a suitable transistor should be selected and provided a suitable dc bias (Fig.6). In this design, the Agilent Technologies High Performance Isolated Collector Silicon Bipolar Transistor HBFP0450 will be used. It will be biased to operate at 2V V_{CE} and 20mA I_C. The model of the transistor used in the simulation can be found in ADS component library (Fig. 5). In this simulation, the DC simulator in ADS is used to make sure the required biasing condition is obtained.
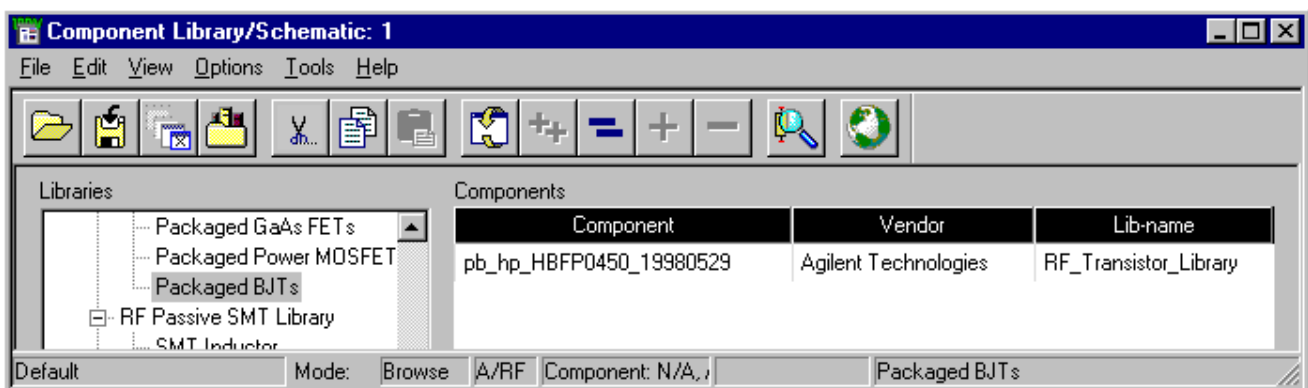

Fig. 5   Transistor HBFP0450 model in ADS

b. Negative resistance

After designed the biasing circuit, the transistor will be constructed as a common emitter capacitive feedback circuit (Fig. 7). This will produce a negative resistance in order to cancel the lost from the resonator. In this simulation, the S_param simulator in ADS is used to get the input impedance of the circuit. From the simulation result, it shows that the overall resistance of the circuit is zero near 2.4GHz (Fig. 8) and it satisfies equation (2). The reactance of the active device is capacitive at this frequency. It means that an inductive resonant tank is needed in this frequency to achieve the 2.4GHz oscillator design.
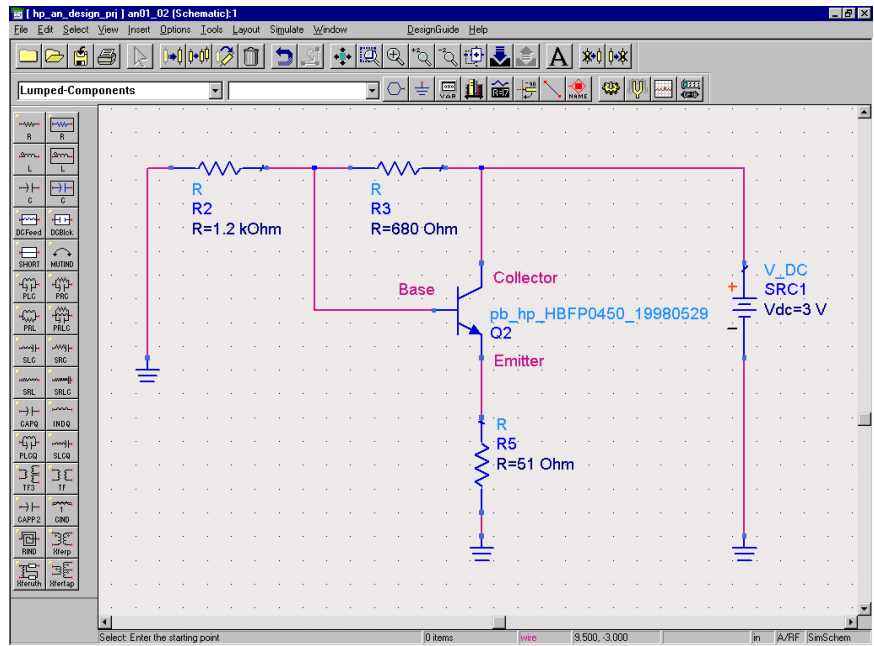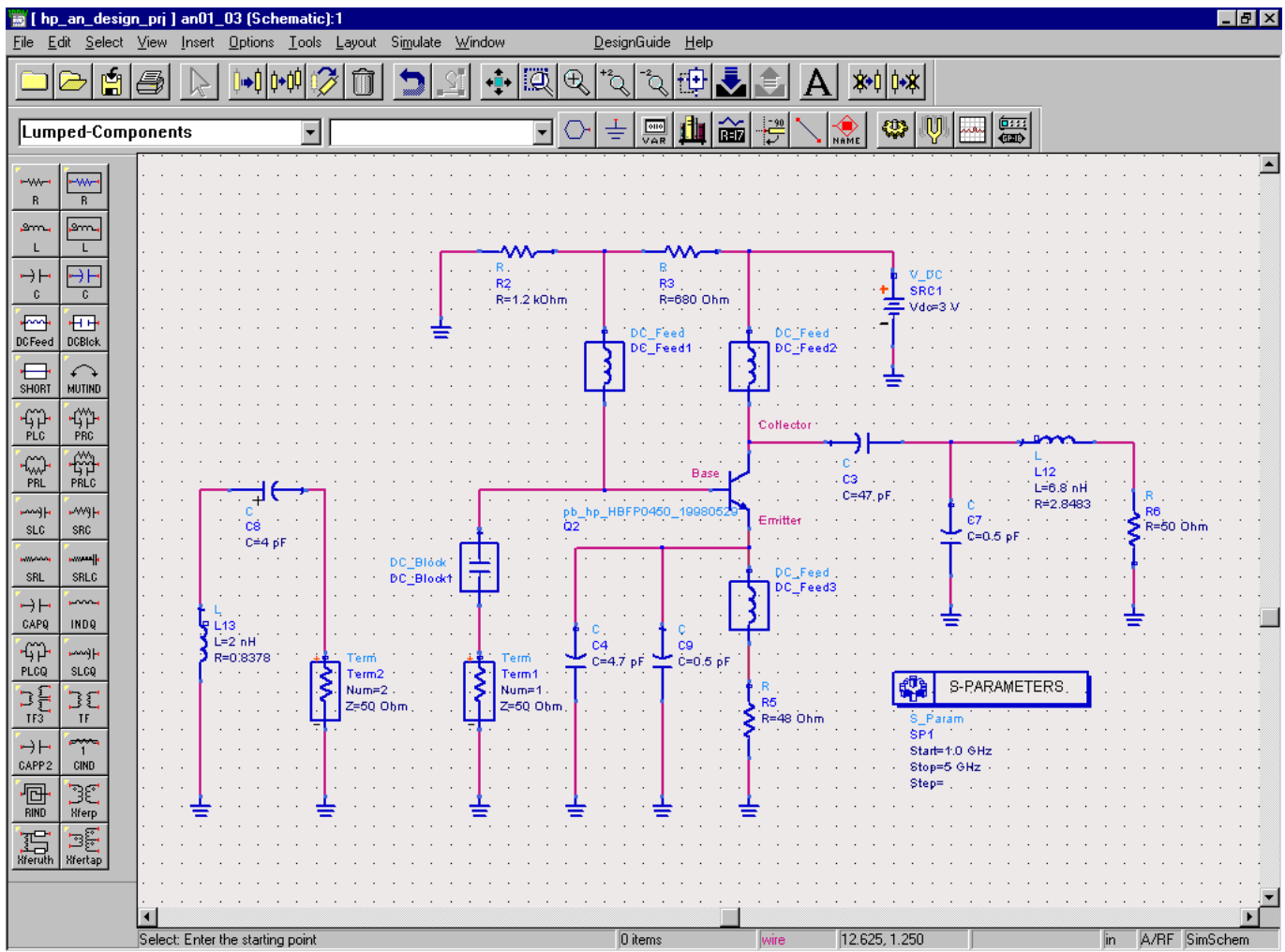

Fig. 6   Biasing circuit

Fig. 7   Negative resistance and resonator simulation circuit

c. Resonator

Now, an inductive resonator is needed in order to make the circuit oscillate. In the resonator, a 4pF capacitor is used to increase the oscillation frequency of the circuit due to the limited value of the lumped inductor. It acts as a dc-block of the resonator also (Fig. 7). The Q-factor of the inductor is assumed to be 36. It will give a lost in the form of a resistor of 0.8378Ω. It is included in the simulation in order to give a more accurate simulation result. The circuit is simulated by the S_param in ADS again. From the simulation result, it shows that the net reactance equals to zero near 2.4GHz (Fig. 8). This satisfies equation (3).
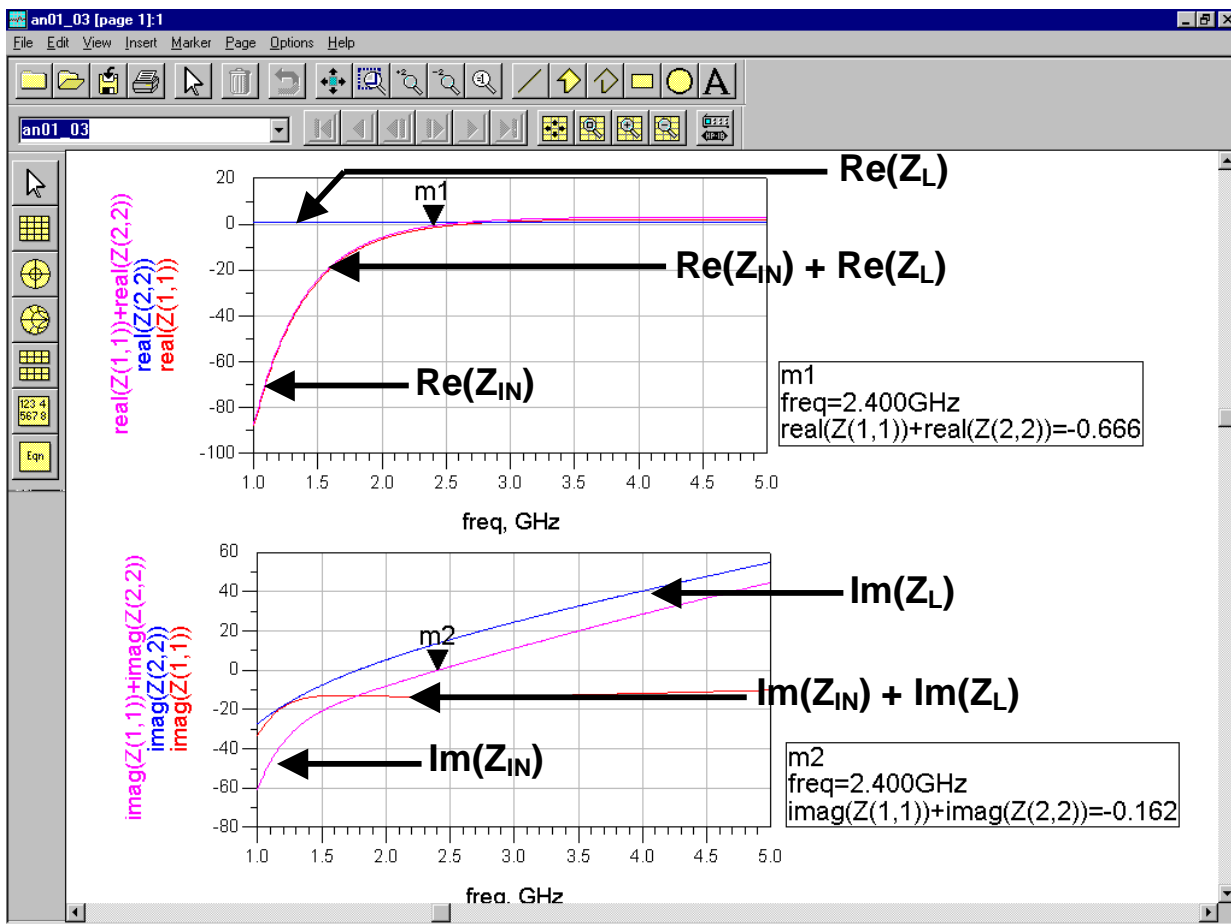

Fig. 8   Negative resistance and resonator simulation result

d. Full simulation and circuit evaluation

By combining the negative resistance and the resonator, the performance of the oscillator can be evaluated now. By modifying the circuit in Fig. 7, an oscillator circuit is obtained (Fig. 9). Here, the HB simulator is used. This simulator can simulate the fundamental frequency, output power and phase noise performance of the oscillator. Besides, the DC simulator will be used again to have a whole evaluation of the circuit.

After the simulation, the performance of the oscillator can be obtained (Fig. 10). The circuit oscillates at 2.4223GHz giving 4.575dBm output power. The circuit phase noise at 100kHz and 1MHz offset are -100.268dBc/Hz and -120.268dBc/Hz respectively. The dc simulation shows the required biasing condition also.
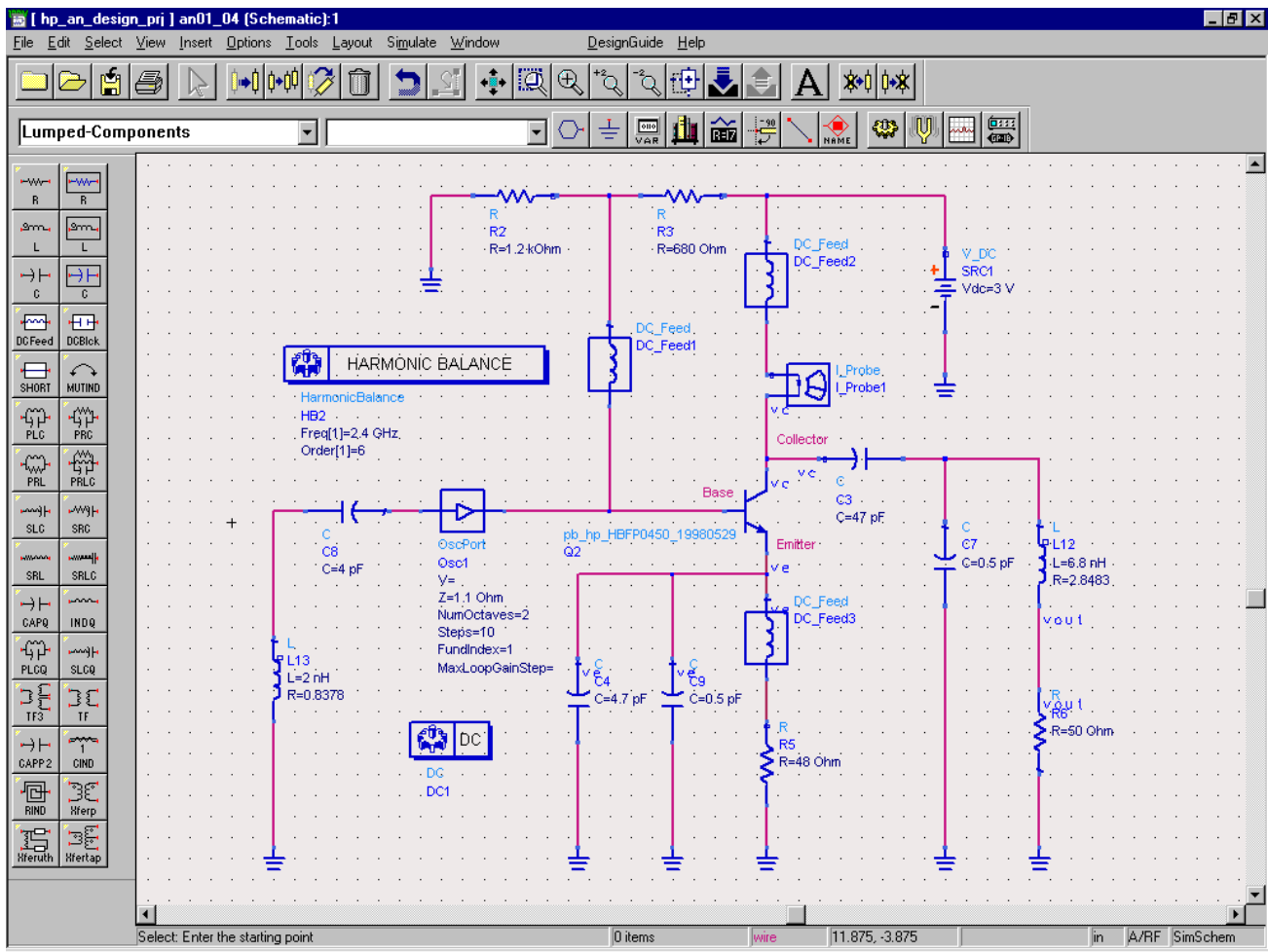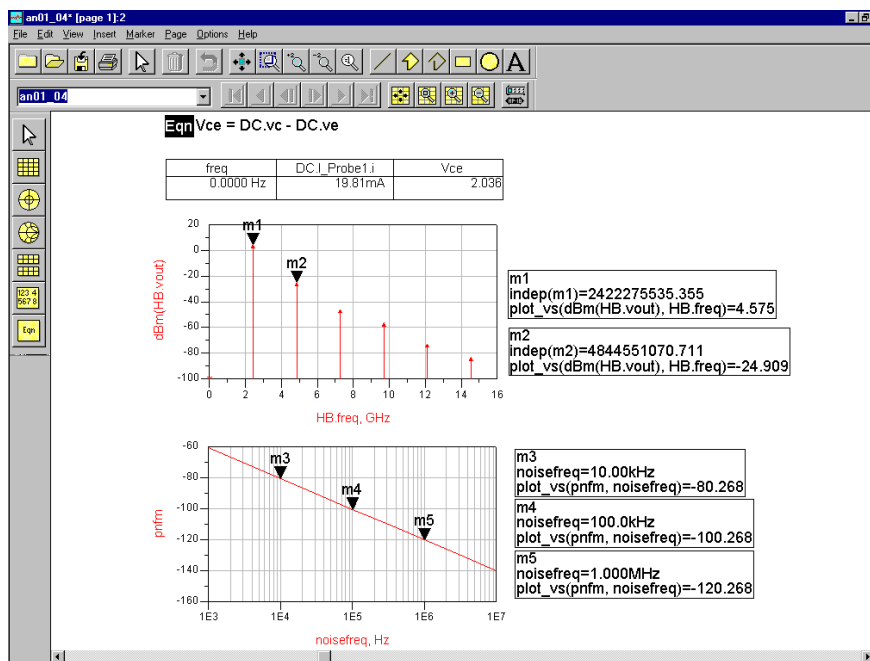
Fig. 9   2.4GHz oscillator circuit

Fig. 10   Oscillator performance

Conclusion

In this application note, a typical negative resistance oscillator designed by using the advanced circuit simulator ADS is presented. By using a powerful simulator, the design time can be greatly reduced and engineers can have a good expectation on the circuit performance before the implementation of the circuit.