An Efficient Technique for Varactor Diode Characterization

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Abstract–An efficient technique for varactor diode characterization is presented. The varactor model is developed using nonlinear CAD tool. The simulation shows excellent agreement with the measured data.

I. INTRODUCTION

In the past, varactors have been characterized using coaxial-line and wave-guide measurement systems [1]-[6]. The complexities of these measurement systems and the parasitics of the structures involved make this type of characterization unattractive from a number of perspectives. Subsequently, McSpadden *et al.* [7] introduced a simpler measurement technique which requires the use of a network analyzer and microstrip circuit test structure. In this paper, an even simpler efficient technique is employed to characterize a typical varactor, over a 3 to 1 frequency range from 500 MHz to 1.5 GHz and with a bias ranging from 0 to 5 volts. An HP8501B network analyzer is used as an essential ingredient for obtaining measurement data. The network analyzer's internal biasing system is used to supply the necessary DC voltage across the diode. Nonlinear circuit optimization software is employed to develop an equivalent circuit model which shows excellent agreement with the measured data.

A. Empirical Characterization

As alluded to above, varactor diode characterization has evolved to the state where modern network analyzers have made the process more efficient. McSpadden has introduced a technique where the full two-port characterization is required. This work demonstrates a highly efficient technique based solely on one-port automatic network analyzer measurements. In this technique, port number two is used solely for biasing and the implications of this will be examined in the ensuing discussion.

To obtain accurate results over the frequency range of interest, a 50 Ohm microstrip line is fabricated using a board of dielectric constant of 2.5 and thickness of 60 mils, as shown in figure 1. One end of the line is connected to the network analyzer, and a hole is drilled near the other end of the line so that there is just enough room for the placement of a varactor diode. The port extension at port 2 is calibrated by shorting microstrip line to the ground. The short is then replaced by the varactor with its cathode connected to the line and its anode to ground.

Biasing is achieved by employing the internal biasing system of HP8510B in the common emitter (BJT) mode. The reverse voltage across the varactor, is then varied by adjusting V_{CE}. Bias tees, which may cause significant error, are eliminated from this measurement technique.

Reflection coefficients are measured for six different biasing conditions, for V = 0 to 5 Volts. For each biasing condition, the network analyzer frequency is swept from 500 Mhz to 1.5 Ghz, which is sufficient for the range of frequency involved. All six sets of data are saved as Touchstone s2p files.

B. Model Development

The general varactor model is developed [7] using the approach of this paper. Utilizing the six sets of measured data obtained from the network analyzer measurements, a nonlinear circuit simulation is employed for model refinement. The model is shown in figure 2, where a 0.5 nh inductor is added to each end of the varactor to simulate the inductance in the actual microstrip board, i.e., short circuit stub and soldering. The optimization process is as follows:

1. Since there are only five components in the model, they are initially treated as variables and given reasonable ranges;
2. The model is then optimized for all biasing voltages. In each case, the optimized values are recorded;
3. Average values for all parameters except the junction capacitance; C_j is selected;
4. Step 2 is repeated with the fixed parameters and the value of C_j is recorded;
5. The C_j data is then used to determine empirically the diode equation

$$C_j = C_0\sqrt{\frac{1}{1-V/m}} \tag{1}$$

where C_0 is zero-bias capacitance, V is the reverse biasing voltage which is negative, and *m* is a factor depending on the semiconductor structure and properties of the diode.

C. Results

The final model of the varactor is simulated and the data is compared to the measured data, as shown in figures 3–8. It is observed from these figures that excellent agreement between modeled and measured data is achieved.

II. Conclusion

A straightforward technique to characterize varactor diodes has been illustrated. The advantage of this technique is that the measurement setup is greatly simplified and an accurate, if not the most precise model developed to date can be rapidly established for precise current design modeling applications.

References

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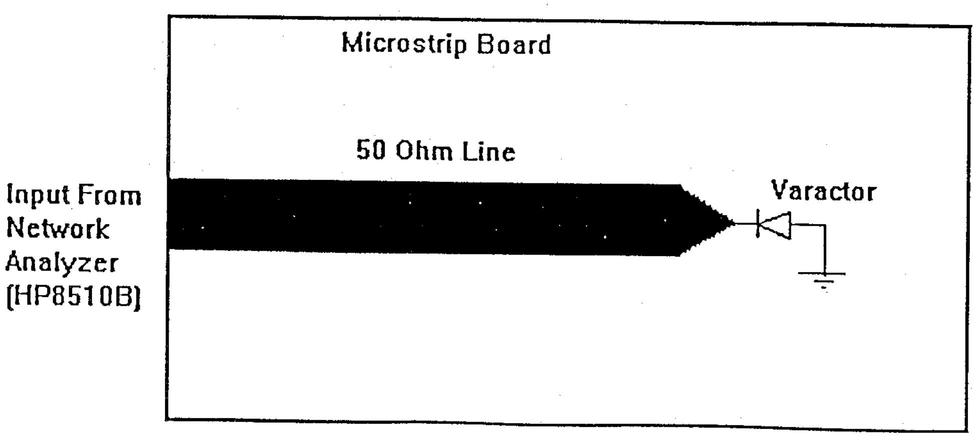

Figure 1: Test Setup for the Varator Characterization

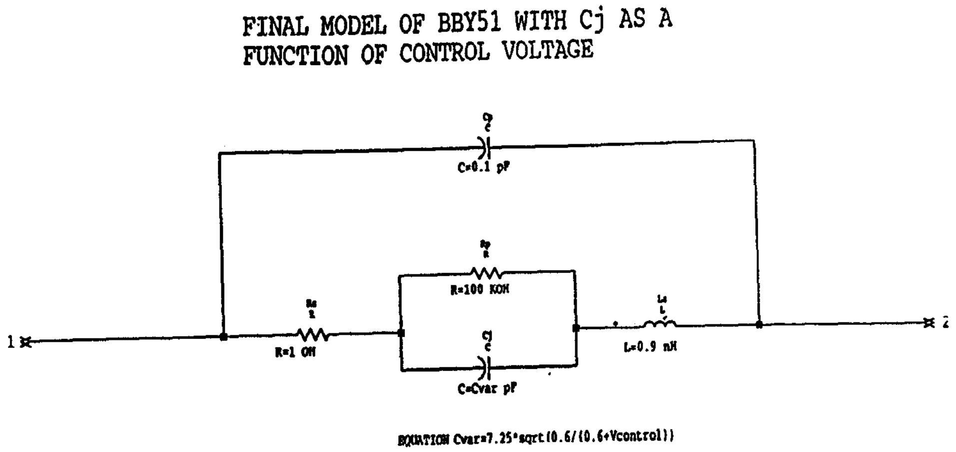

Figure 2: Varactor Model

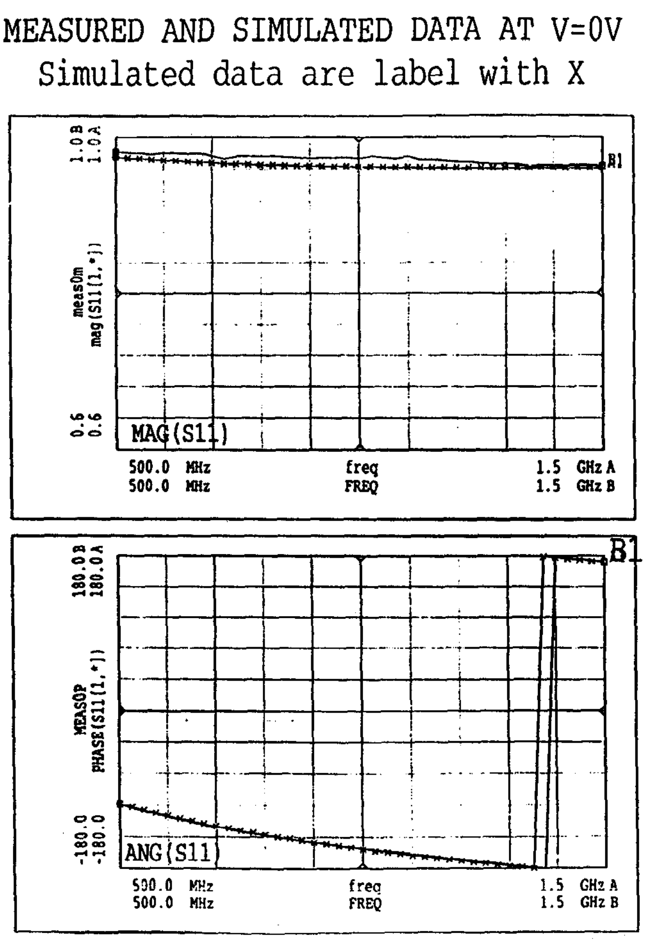

Figure 3: Measured and Simulated Data at V_{Bias} = 0V

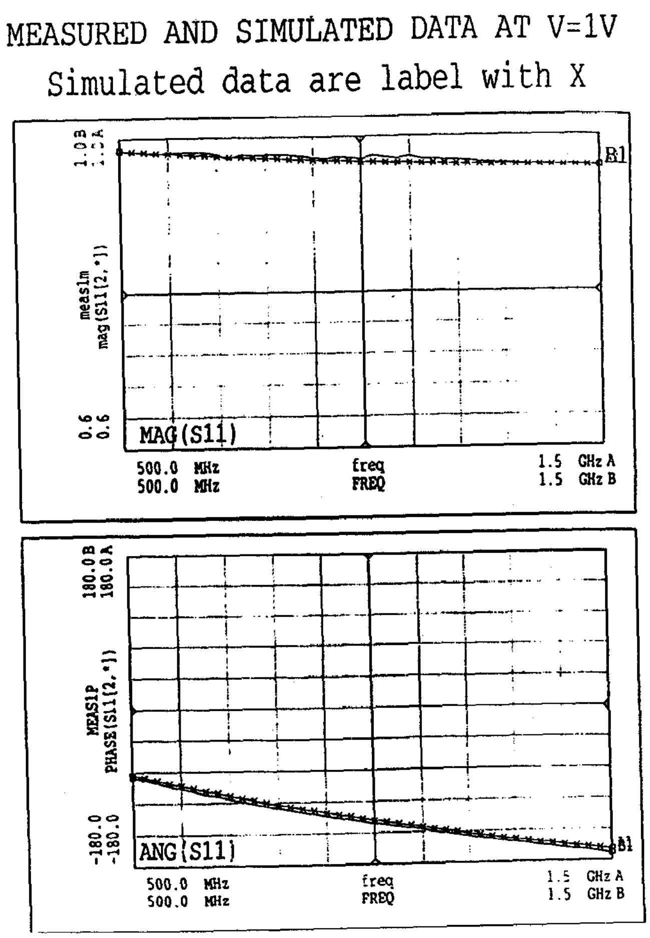

Figure 4: Measured and Simulated Data at V_{Bias} = 1V

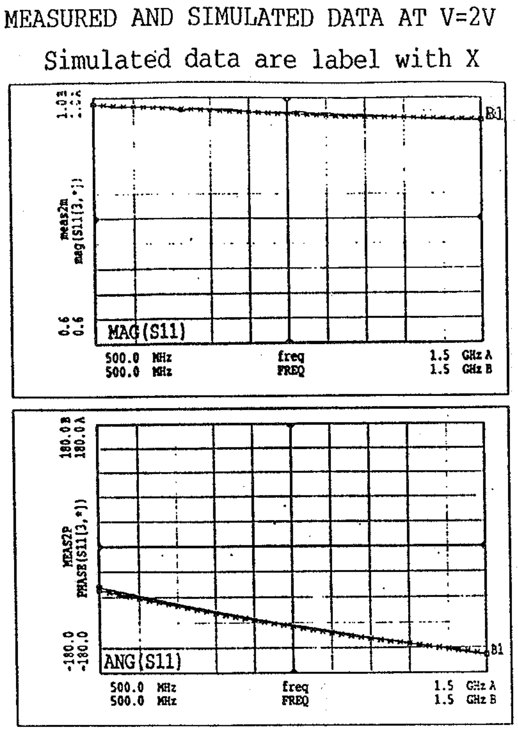

Figure 5: Measured and Simulated Data at $V_{Bias} = 2V$

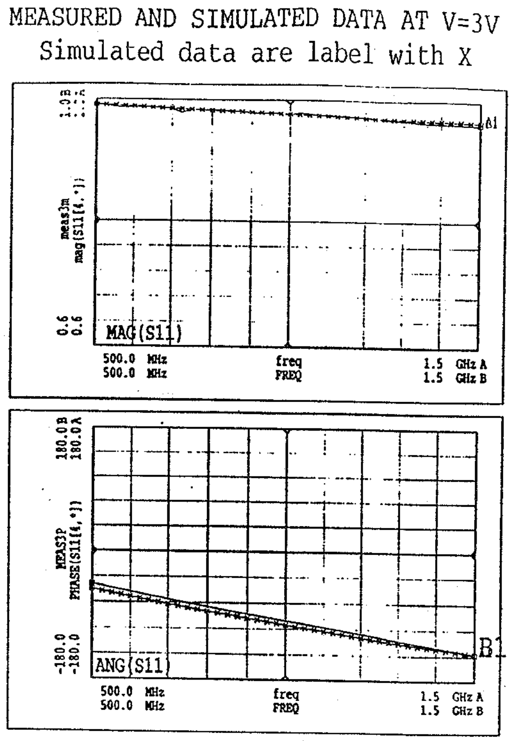

Figure 6: Measured and Simulated Data at $V_{Bias} = 3V$

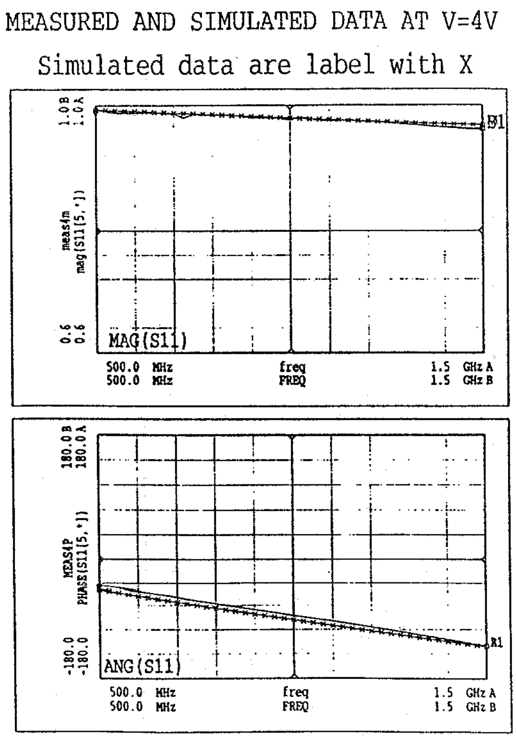

Figure 7: Measured and Simulated Data at $V_{Bias} = 4V$

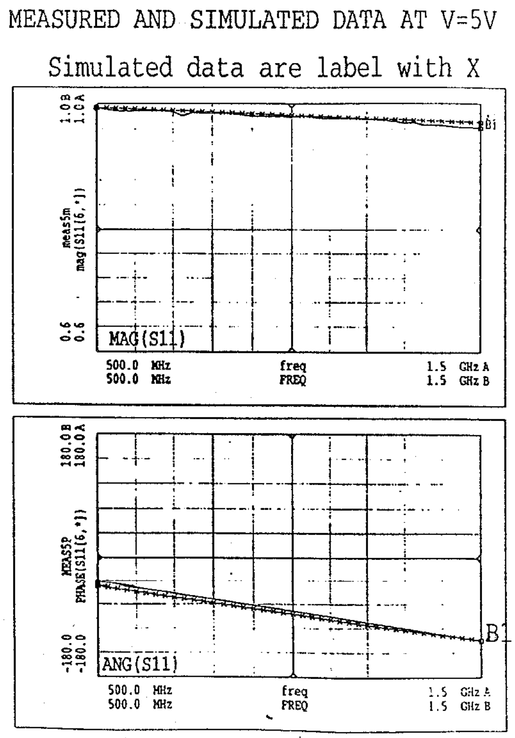

Figure 8: Measured and Simulated Data at $V_{Bias} = 5V$