AMPLIFIER LINEAR PERFORMANCE

Lab #9

This lab includes the final construction of the amplifier you've designed, as well as the characterization of its linear performance (i.e. small-signal frequency response using the vector network analyzer). Comparison between actual performance of the completed amplifier with simulations will be made to provide insight into the limitations and strengths of computer-aided design methodologies. Subsequent labs will characterize the noise and non-linear performance of the amplifier to complete the performance picture.

Amplifier Construction

Construct the dc bias network that you designed in Lab #7 on a piece of perfboard. Look at one of the example amplifier boards to see how to add the chip bypass capacitors to the ends of the bias stubs and how to use the small vias and/or brass tacks available in the lab to provide connections through the substrate to ground the capacitors. Using the shortest practical wires, attach the dc bias network to the capacitor-terminated end of the bias stubs.

Install the AT-42085 or AT-41485 transistor in the middle of the line. To install the transistor, first look at the example board in the laboratory; it is extremely important that you use extreme care in installing the transistor. Use a small drill bit to bore a via hole for the emitter connections (it is helpful to drill two holes directly adjacent to each other – see the example board), and use a sharp knife to create a "recess" for the transistor to sit in. This recess is required because the emitter leads are not long enough to reach the ground plane if the transistor is not mounted precisely. Solder the transistor in place; the base should be connected to port 1, the collector to the right-hand port 2, and the two emitter leads should be bent to go through the via hole and be soldered to the ground plane on the back side of the board.

This completes the basic construction of the microwave amplifier; if all has gone well, the amplifier should have a bandpass response centered at (or at least near) your design frequency.

Linear Amplifier Performance Measurement

In order to verify that your amplifier works as designed, it is necessary to measure the frequency response obtained "as-built," and then make any adjustments necessary to achieve proper operation.

1.) Since the amplifier has significant gain, it is necessary to engage the attenuators that are internal to the network analyzer to avoid overloading the analyzer. Use a port power of –35 dBm, Set the frequency range to measure from 300 MHz to 6 GHz with 401 data points to get good frequency resolution. **Failure to properly set these port powers, or attempting a measurement below 300 MHz can damage the network analyzer due to excessive power.** The easiest way to do this is to use the same basic ICCAP control file as we used for measuring the "bare" transistor, but without any need for the base and collector bias settings (since these are now controlled by your biasing circuitry). If you are uncertain about these settings, please ask the instructor before proceeding. Once the power and frequency ranges are set, perform a full two-port calibration (using the SMASOLT calibration kit) to remove systematic measurement error in the analyzer.

2.) With the circuit dc power disconnected, connect the amplifier board to the analyzer, with the base line connected to port 1 and the collector line connected to port 2. Check, then double-check all connections. Have the instructor check your circuit connections and calibration settings **before** applying power to the circuit.

3.) Turn on the dc power to the circuit, and record the s parameters. S_{21} should show significant gain at your design frequency, dropping off significantly above that. For high-gain amplifiers, S_{11} and S_{22} should have fairly "deep" return loss dips at or near the design frequency. For a low noise amplifier, the input return loss may not be very large, but the output S_{22} should show a deep dip at the design frequency. If you see "spikes" on the measured characteristics or if the return loss at the input or output are larger than 0 dB, this is an indication that the circuit may be oscillating; this has to be fixed before proceeding. Judicious application of capacitance in the bias network is often sufficient to improve this. Once the amplifier is working correctly, save the measured s-parameters for comparison with the simulations from the CAD software.

4.) You should also obtain magnitude and phase plots of all 4 s-parameters for inclusion in your lab notebook, since this is the main measure of microwave amplifier performance.

Comparison of Amplifier Performance with Simulation

1.) In ADS, build a model of your amplifier, including the effects of the connectors (the discontinuity and electrical length). Use the microstrip parameters that you obtained from optimization in lab 6.

2.) Obtain plots of the amplifier performance predicted by the simulator. Compare the results of the simulation to those obtained by direct measurement. Discuss the origin of any discrepancies observed. Doing "what if" simulations are often useful as a way to understand why the circuit doesn't do quite exactly what was expected.

Stability Analysis of Transistor S-Parameters

Using the measured s-parameters for your biased microwave transistor (data collected in Lab #7), determine the regions of stability (source and load terminations) for the transistor. Is your transistor unconditionally stable at your design frequency? How about at other frequencies in the range measured? For frequencies spanning the frequency range measured, plot the stability measure (μ) to see what frequencies could be potentially unstable. Plot source and load stability circles on Smith charts (ADS has built-in functions to plot stability circles which you may find helpful) at a few frequencies of potential interest. Check your matching network solution over the frequency range from 300 MHz to 6 GHz to insure that the source and load terminations it presents to the transistor lie in the stable regions for the full measured frequency range.