The goal of this project is to design several broadband amplifiers. You will use two different devices for this project.

**Part 1- Resistive feedback amplifier**

1.1. In class, we mentioned that a relatively high transconductance is needed for a good resistive feedback design, so we will use a bipolar device for this part of the project. Using the parameters/spec sheet of the BFG591 transistor (see device models on web page) at 12V, 90mA bias, design a broadband feedback amplifier from 100MHz-1GHz (decade bandwidth). The transistor is a silicon bipolar transistor from NXP (formerly Phillips) with a 7-GHz cutoff frequency. Use both series and parallel feedback: a 300-Ω resistor in between collector and base and a small (5-10Ω) resistance in the emitter. For biasing, use a 1000pF blocking capacitor and to bias the base, use a 10k resistor. Use another blocking capacitor in the feedback to make sure your base bias does not get into the collector. Use a 1µH inductor for the collector bias.

(1) First, only put the series resistor in the feedback between collector and base. Then, add an inductor (a few tenths of nH) in series, as shown in the figure. What is the effect of the inductor?

(2) Show a possible physical layout of the feedback amplifier circuit that you would be willing to implement.

1.2. Simulate the performance and provide all relevant simulation plots and associated comments in your report.
**Part 2- Balanced Amplifier**

2.1. Design a gain-matched amplifier, or use your amplifier from Project 1. Summarize the performance, we will use this as a benchmark.

2.2. Design a balanced amplifier with Wilkinson combiners, or coupled-line (e.g. Lange) couplers. The two amplifiers in the balanced amplifier should be the ones you designed in the previous part. Start by simulating two couplers back-to-back, then add just the transistor with no matching circuits or bias lines for the two amplifiers, and then include the matching circuits from part 2.1. Compare in each case the gain and bandwidth with the single amplifier from (2.1). Include bias lines in the final design.

2.3. Summarize your simulations in one or two plots and show the layout of the balanced amplifier in your report.

**Part 3- Distributed and Traveling-wave Amplifiers**

3.1. Search the literature (IEEE MTT transactions, IEEE IMS are good sources) to find at least 5 references for distributed amplifier and traveling wave amplifiers and summarize their performance in a table. Give a brief summary of your favorite one.

3.2. Simulate a distributed amplifier using the simple model we did in class (Lecture 4). De-embed Cgs and Cds from your device S-parameters at some relatively low frequency, using the Y-parameter method we did in class. You might need to make some approximations as you do this. After finding the capacitances, chose inductor values and simulate the performance as a function of number of stages. For your favourite number of stages, now add rds that you have estimated from the S-parameters, and discuss how this changes the behavior.

NOTE: a two-port model for a dependent current source in a transistor model does not exist in all simulators, and here is how you can implement it:

\[
S = \begin{bmatrix} 1 & 0 \\ s_{21} & 1 \end{bmatrix}, \quad \text{where } s_{21} = -2g_m Z_{0s_{21}}
\]