Problem Set 5
Due Monday April 20, 2009

1. Assuming sinusoidal pulse currents of a given duty cycle y, a knee-voltage of V_k, maximum drain current I_{max}, and a breakdown (supply) voltage of V_{bk},

    (a) Calculate the range of duty cycles y for which the PA is perfectly linear. In other words, the output power is linearity proportional to the input amplitude. *Hint: Class A is linear. Are there other classes that satisfy the linearity constraint?*

    (b) Verify that the drain efficiency and normalized output power are given by

    $$\eta_D = \frac{1}{2} \left[\frac{1 - \frac{V_k}{V_{bk}}}{1 + \frac{V_k}{V_{bk}}} \right] \left[\frac{y - \sin(y)}{2\sin(y/2) - y\cos(y/2)} \right]$$

    $$p_o = \frac{P_o}{V_{bk} \cdot I_{max}} = \frac{1}{8\pi} \left[\frac{y - \sin(y)}{1 - \cos(y/2)} \right] \left[1 - \frac{V_k}{V_{bk}} \right]$$

    (c) Based on the above equations, for a given technology (V_k, V_{bk}, and I_{max}), there is an optimal Class of operation (duty cycle) point of operation. Find this point for $V_k = 0$V and explain why the power is higher than Class A operation.

2. Design a PA in a bipolar technology delivering 500mW to a 50Ω load at 2.4GHz . The PA should be a single device with a matching network. Assume lumped Q factors as high as 30 are possible. Assume that the maximum supply voltage of 3V and a collector breakdown voltage of 7V. Bias the PA in any class of operation and target the highest peak efficiency possible. Assume the emitter of the device is grounded through a down-bond with a net inductance of 300pH. For simplicity, assume a unit device with 10fF of C_{je}, a forward transit time τ_F corresponding to a 100GHz transit frequency when biased with a collector current of 1mA, and a β =100. Use the multiplicity factor m to size the actual device.Plot the input/output power and the collector efficiency for the PA. Be sure the PA is stable and biased correctly.

3. For your PA, find the highest power level that satisfies $IM_3 > 40$ dBc when two carriers spaced 1 MHz apart are input to the PA (note that you should consider the *sum* of the carrier powers and assume that they are in phase). What is the efficiency for this power level? What is the efficiency of your PA if you drive it with a signal with this average power level but with a Gaussian statistics. Assume the standard deviation of the signal is equal to the average. Note that the signal will actually clip when the signal level exceeds the capabilities of your PA. For simplicity numerically integrate the clipped Gaussian profile in your efficiency versus power curve.