CARLETON UNIVERSITY

FINAL
EXAMINATION
April 2011

DURATION 3 HOURS No. of Students 8

Department Name & Course Number: Electronics ELEC 5705
Course Instructor(s): Prof. John W. M. Rogers

AUTHORIZED MEMORANDA	Calculators, Course Notes

Students MUST count the number of pages in this examination question paper before beginning to write, and report any discrepancy immediately to a proctor. This question paper has 6 pages.

This examination question paper MAY **be taken from the examination room.**

Information and Instructions:

1. Attempt all questions.
2. Show all analysis.
3. The exam marks total 100.

Potentially Useful Equations:

$$v_{DS\,Sat} = v_{GS} - V_T,\ V = IR,\ C = \frac{q}{V},\ i_D = \frac{1}{2}\left(\mu C_{ox}\right)\left(\frac{W}{L}\right)\left(v_{GS} - V_T\right)^2$$

$$v_{DS\,Sat} = v_{GS} - V_T = \sqrt{\frac{2i_D}{\mu C_{ox}}\left(\frac{L}{W}\right)},\ E = mc^2, c = \frac{1}{\sqrt{\mu\varepsilon}}$$

$$r_{DS} = \frac{1}{\lambda I_{DS}},\ i_{nd}{}^2 = 4kT\left(\frac{2}{3}\right)g_m,\ \text{kT} = 4\cdot10^{-21}\text{W/Hz at T=290K, q} = 1.6\cdot10^{-19}\text{C}$$

$$g_m = \sqrt{2\mu C_{ox}\left(\frac{W}{L}\right)I_{DS}},\ \Gamma = \frac{Z_L - Z_o}{Z_L + Z_o},\ \nabla\times\vec{E} = -\mu\frac{\partial\vec{H}}{\partial t}$$

$$a = \frac{dv}{dt} = \frac{d^2x}{dt^2},\ Money = Power = VI = I^2R = \sqrt{Evil}$$

$$R_{on} = R\cdot\frac{L}{W}$$

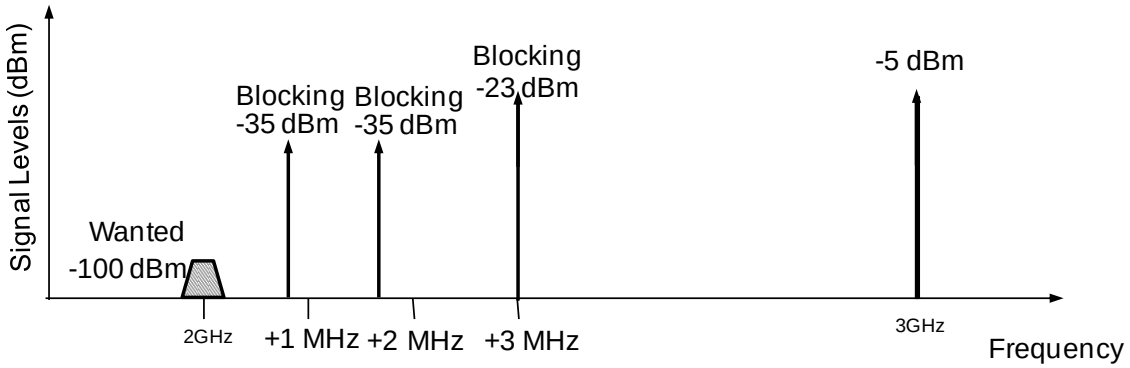
Question 1 (Total 25 Marks) (To be completed while juggling pinless hand grenades.)

You are to design a communications link to operate in an urban environment. The link is to be able to transmit over a distance of 10km with a BER of 10^{-3}. The bandwidth available for the link is 10MHz at 2GHz. Five simultaneous conversations must be able to take place. The data rate is to be 3.5MBits/s. The receiver in this system can be designed to have a noise figure of 8dB. Determine:

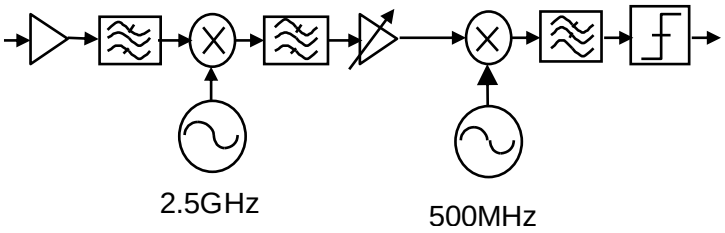
a) The required transmit power.
b) The style of OFDM modulation you would need. Assume 25 subcarriers are used
c) The number of subcarriers required to carry data.
d) Two alternate uses for the subcarriers (specify which sub carriers) other than carrying data.
e) Two advantages of OFDM over single carrier and one disadvantage.
f) Why no guard band is required between subcarriers.

Question 2 (Total 25 Marks) (To be completed while dodging boiling hot pizza slices being thrown at your head by Steven Harper.)

The following signals are fed into a radio receiver. The bandwidth of the signal is 50kHz, but spaced every 1MHz.



The receiver block diagram is shown below:

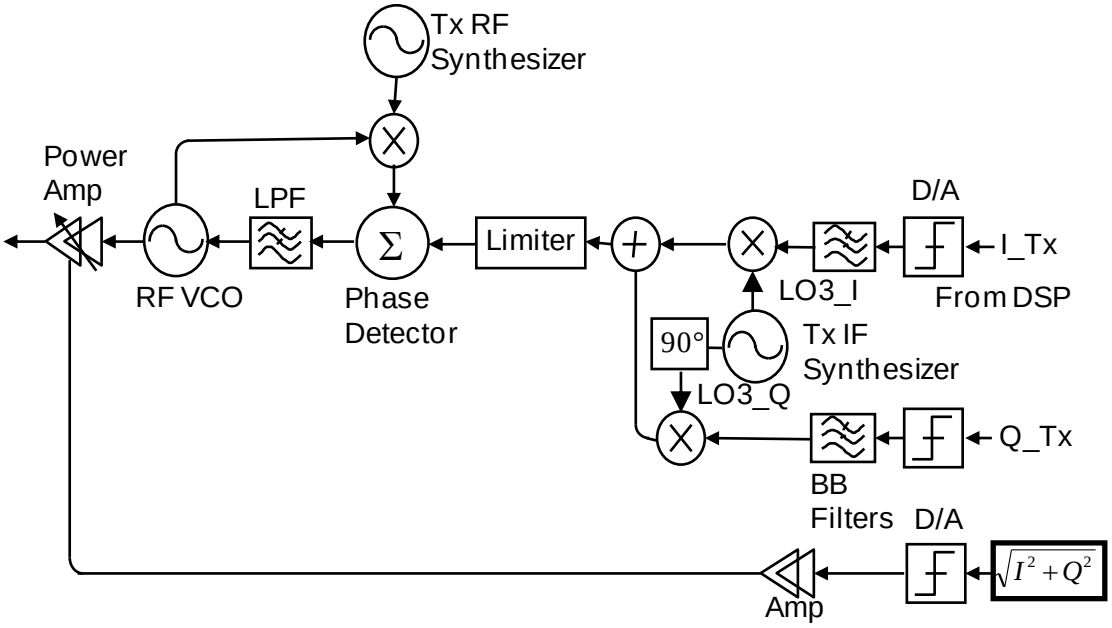


You must design the components of the radio to deliver a signal to the base band with a SNR of at least 10dB. In order to do this fill in the following table at a minimum:

Component	Parameters
LNA	Gain: 15 dB NF: _____dB IIP3: -5dBm
Image Filter	Insertion Loss: 2dB Passband: 2GHz Bandwidth: 10MHz Attenuation at 3GHz:_____
RF Mixer	Voltage Gain: 3 dB NF: 10 dB IIP3:_____dBm
IF Filter	Insertion Loss: 2dB Passband: 500MHz Bandwidth: _____MHz Attenuation at 1MHz offset:_____ Attenuation at 3MHz offset:_____
IF Amplifier	Voltage Gain: _____ dB NF: 15 dB IIP3: _____dBm
ADC	Input voltage: 1Vpp Sampling frequency: 1MHz Number of Bits: _____ Clock Jitter:_____
RF Synthesizer	Adjacent channel spur level: _____dBc

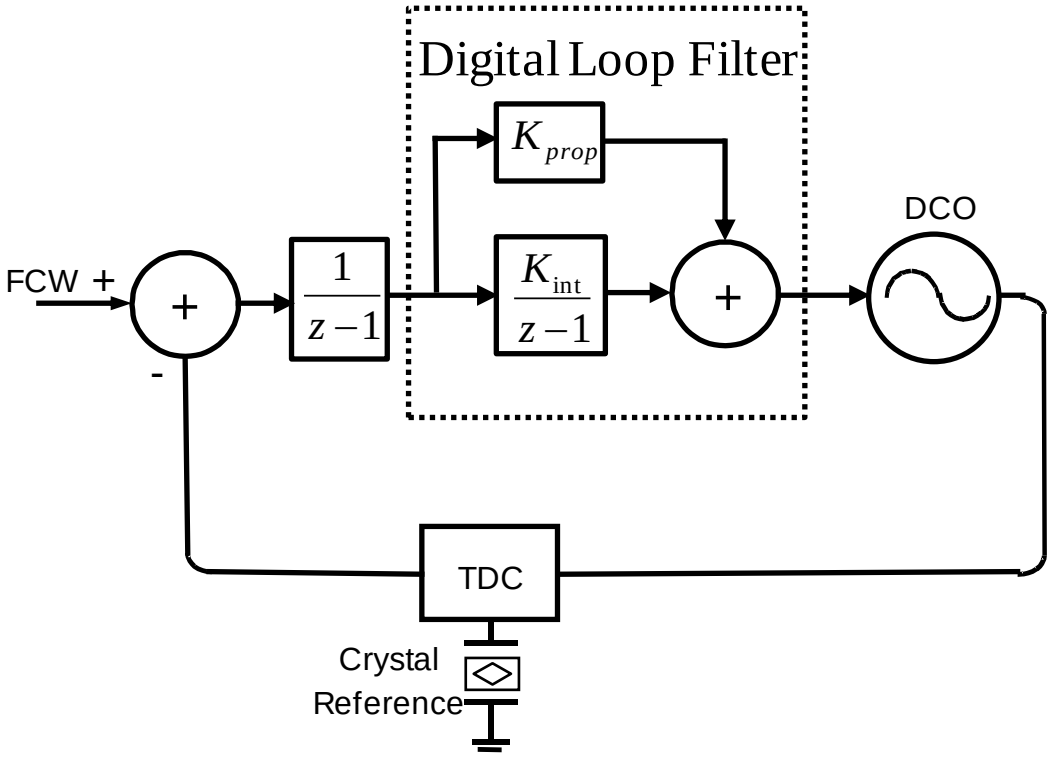
Question 3 (Total 25 Marks) (To be completed while driving a car loaded with dynamite directly into the sun.)

The following transmitter is to be used in a full duplex transceiver. The Tx band is to be 4.0-4.05GHz and the Rx band is to be 4.1-4.15GHz. The system is to use a 64 subcarrier OFDM modulation with an RF bandwidth of 5MHz. You must specify: RF and IF frequency synthesizer frequencies, IQ phase matching, phase noise (must be fully specified at all frequencies of importance) and transmitter linearity. The adjacent channel power must be lower than -30dBc, and the SNR must be greater than 12dB. The duplexor will provide 30dB of isolation. The transmit power is to be 20dBm and the minimum receive power is to be -90dBm. Name at least one major advantage of this architecture in this situation.



Question 4 (Total 25 Marks) (To be completed while locked in a cage with a cocaine snorting gorilla dressed as a clown.)

Consider a basic all digital phase locked loop like the one shown below.



a) For a reference frequency of 40MHz, and an output frequency of 2GHz design the loop to have a damping constant of 0.707 and a natural frequency of 100kHz.

b) Assume that FCW = 5.25 fill out the following table assuming that the TDC is a simple integer counter and the loop is in lock and that at the start the DCO and reference are in phase at the start of the first cycle. Determine the frequency offset of the closest spur.

Reference Cycle	TDC Count	Error	Actual number of DCO cycles since start
1			
2			
3			
4			
5			
6			
7			
8			

c) Assume that FCW = 5.25 fill out the following table assuming that the TDC includes a fractional counter. The fractional counter is simple and produces a 1 for more than half a cycle and a zero for less than half a cycle (it has a half cycle resolution). The loop is in lock and that at the start the DCO and reference are in

phase at the start of the first cycle. Determine the frequency offset of the closest spur.

Reference Cycle	TDC Count	Error	Actual number of DCO cycles since start
1			
2			
3			
4			
5			
6			
7			
8			

d) Estimate the in band phase noise produced by a ADPLL in (a) assuming that the resolution of the TDC is 30ps.

e) What real life property of the DCO could make the calculation done in (d) useless?