ECE 6390: Satellite Communications and Navigation Systems
Solutions to TEST 1 (Fall 2006)

1. **Short Answer Section** (**19 points**)

   (a) momentum wheels (1) spinning (2)

   (b) certified

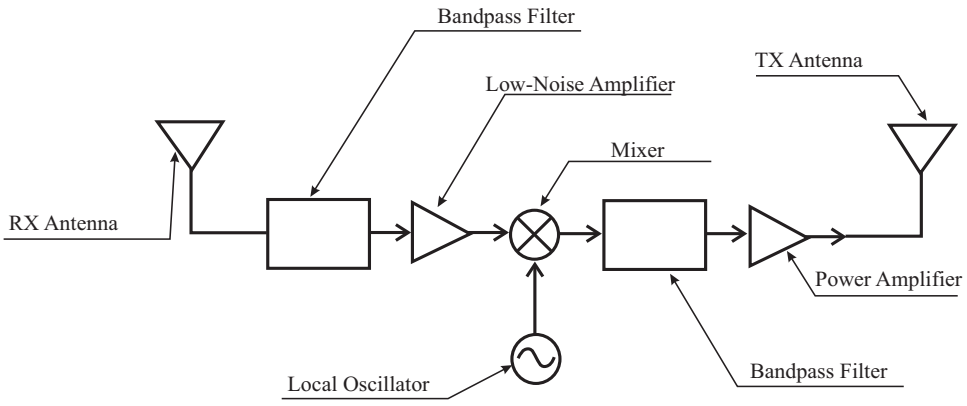
   (c) ion

   (d) Helmholtz

   (e) **Famous Dates:** Match the dates below to the events.

g	1630	a) First satellite *Sputnik* launched by USSR
c	1945	b) GT's most recent football championship
a	1957	c) Arthur C. Clarke publishes "Extra-Terrestrial Relays"
e	1958	d) Telestar I and II launched by Bell Labs
d	1962	e) *Explorer I*, first US satellite is launched
h	1969	f) First mobile satellite telephone networks launched
i	1980s	g) Johannes Kepler born
f	2000	h) Moon landing
b	1990	i) Global Positioning System launched

2. **Satellite Transponder:**



3. **LO Leakage:** A *radar detector* would use a low-side local oscillator of 15.515 GHz to mix down a 15.525 GHz carrier to 10 MHz. A *radar detector detector* would use a low-side local oscillator of 15.505 GHz to mix down a 15.515 GHz leaked LO to 10 MHz. A *radar detector detector detector* would use a low-side local oscillator of 15.495 GHz to mix down a 15.505

GHz leaked LO to 10 MHz. And, finally, a *radar detector detector detector detector* would use a low-side local oscillator of 15.485 GHz to mix down a 15.495 GHz leaked LO to 10 MHz.

4. **Deep Space Orbits:** We use Kepler's 3rd law to calculate the total transit time of the first half-orbit, the second full orbit, and the final half-orbit:

$$T = \frac{2\pi}{\sqrt{\mu}} \left[\frac{1}{2} \left(\frac{R_{\text{ear}} + R_{\text{ven}}}{2} \right)^{\frac{3}{2}} + \left(\frac{R_{\text{ven}} + R_{\text{aph}}}{2} \right)^{\frac{3}{2}} + \frac{1}{2} \left(\frac{R_{\text{ven}} + R_{\text{sat}}}{2} \right)^{\frac{3}{2}} \right]$$

   This results in 2.36×10^8 seconds, which is about 7 years and 7 months.

   Our crude calculation made some assumptions about this trajectory that are not necessarily true: 1) planetary orbits are circular, 2) perfect full or half-orbits constitute the slingshot Cassini paths, and 3) the slingshot is instantaneous in time, immediately changing the orbit of the satellite. The above calculation puts the arrival of Cassini somewhere around May 2006. In fact, the satellite arrived on 1 July 2004, having received a modest slingshot boost from a nearby pass of Jupiter that we did not consider in our formulation.

5. **Link Budget for a Deep Space Communications:** According to the Shannon Channel capacity, we must theoretically have a minimum SNR of -3.8 dB. Since the noise power of this system is -155.6 dBW, we require a minimum received power of -159.4 dBW (more noise power than signal power is perfectly OK in digital communication). When we plug this into the link budget equation with the other given parameters, we find that the maximum communication distance is 2.5×10^{11} meters.