Final Exam, Winter Quarter 1999
100 points

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1. (20 points) Consider a surveillance satellite in circular orbit with repetition factor $Q = 15$ and inclination $IN = 90°$. At time $t_0$ this satellite passes over the equator at (0N, 10E) from south to north.

a. What is the period of this satellite in seconds?

b. What is the altitude of this satellite in kilometers?

c. What is the distance to the horizon for this satellite?

d. What will be the longitude of the next south-to-north equator passage of this satellite?

Suppose this satellite is carrying a sensor with lateral range function of

$$l(\delta) = \max\left(0, .46 - \frac{2\delta}{100}\right),$$

where $\delta$ is the minimum angular distance in degrees between the target and the subsatellite point (i.e., the angular "lateral range" in degrees).

e. For a target at (0N, 0W), what are the probabilities of target detection on the current pass (equator crossing point: (0N, 10E)) and on the next south-to-north pass?

f. Assuming repeating ground tracks, probabilistic independence from pass to pass, and considering only the south-to-north passes, evaluate
($i$) the probability of detection each sidereal day, and
($ii$) the mean number of sidereal days to detection.

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2. (20 points) An aircraft on course 000° at speed 170 m/sec is illuminating a target aircraft bearing 000° on course 090° at speed 110 m/sec. The radar has a frequency of 15 GHz.

a. What is the wavelength of the 15 GHz radar?

b. What is the frequency of the radar signal received by the target aircraft?

c. What is the frequency of the echo radar signal received by the transmitting aircraft?

d. What would be the answers to b. and c. above if the target aircraft was on course 060°?

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3. (20 points) Artillery rounds impact at random point $(X, Y)$, where $X \sim N(0 \text{ m}, 625 \text{ m}^2)$ and $Y \sim N(0 \text{ m}, 2500 \text{ m}^2)$. Friendly observers are located at (50 m, 150 m). If a rounds lands within 20 m of the friendly position, the friendly is assumed to be damaged.

a. If 1 round is fired, what is the probability that it will damage the friendly site?

b. If 10 rounds are fired, what is the probability that one or more will damage the friendly site?

c. If the friendly site can be moved 50 meters in any direction, which direction would you recommend to minimize the probability of damage?

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4. (30 points) Answer each question either true (T) or false (F). Each question is worth 2 points.

(a) (  ) The $(\lambda - \sigma)$ model always gives a positive probability of detection at time 0.

(b) (  ) In the $(\lambda - \sigma)$ model, the cumulative probability of detection increases as $\lambda$ increases.

(c) (  ) The continuous looking model always gives a probability of detection of 1 as $t$ increases to infinity.

(d) (  ) When searching an <u>expanding disk</u> using random search, eventual detection is certain.

(e) (  ) When dividing a specified amount of search effort over a finite number of cells to maximize $P_d$, it is <u>not</u> necessary to first search in that cell maximizing detection rate.

(f) (  ) The myopic search always places the next increment of search into that cell maximizing detection rate.

(g) (  ) If the semimajor axis of a satellite increases by a multiplicative factor of $k$, the period increases by a multiplicative factor of $k^{1.5}$.

(h) (  ) If a satellite's repitition factor $Q$ is 4.5, then the period is SD/Q, where SD is the length of one sidereal day.

(i) (  ) If a satellite's repitition factor $Q$ is 4.5, then ground tracks repeat every 2 days.

(j) (  ) A satellite with orbital inclination of 60° can have its ground track pass over a target with latitude 55°.

(k) (  ) Precession of the ascending node is maximal for low Earth orbiters in equatorial orbits.

(l) (  ) Precession of the perigee is maximal for low Earth orbiters in equatorial orbits.

(m) (  ) Using the ROC methodology, it is possible to achieve probability of detection ($P_d$) of 1, if an associated probability of false alarm ($P_f$) of 1 is acceptable.

(n) (  ) For a signal in Gaussian noise (either known or unknown), if the detection index is 0, then $P_d = P_f$ and the ROC curve is linear.

(o) (  ) The area of the "cocked hat" can decrease as additional bearing lines are added.

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5. (10 points) The actual bearings from a target to observers 1, 2 and 3 are 060°, 180° and 300° respectively. At a specified time, each observer records a bearing to the target. Unfortunately bearings to the target have errors in them. For each observer, the probability that the recorded bearing line falls to the right of the target ($P_R$) is 1/3, and the probability that it falls to the left ($P_L = 1 - P_R$) is 2/3.

a. For this target/observer geometry, which cases (e.g., $LRL$, $RRL$, $RLL$) cause the target to be inside the "cocked hat"?

b. What is the probability of the target being inside the cocked hat?

c. What value of $P_R$ would maximize this probability?