1. A surface to air missile (SAM) site is receiving position information about your aircraft. Jamming seems like a good idea, so you turn on your jamming equipment. The parameters for the radio transmitter and your jamming equipment are given below. If the SAM site needs a signal to noise ratio of 0.06 to process and receive the communication signal, is your jamming effective?

SAM radio communications	**Your jamming equipment**
Power transmitted = 1 kW	Power transmitted = 2.0 kW
Transmit Antenna Gain = 3	Transmit Antenna Gain = 20
Receive Antenna Gain = 3	
Frequency = 750 MHz	Frequency = 750 MHz
Distance = 80 km	Distance = 75 km

(a) What is the wavelength of the signal? $\lambda =$ 400 mm

$\lambda = c/f = (3 \times 10^8)/(750 \times 10^6) = 0.4$ m $= 400$ mm

(b) What is $P_{received}$ of the SAM radio without jamming, i.e. the signal power? Hint: Use Friis. $P_R =$ 1.425 nW

The signal S: Friis from the SAM radio's transmitter, over its own 80 km.

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi R}\right)^2$$

$$= (1000)(3)(3)\left(\frac{0.4}{4\pi(80{,}000)}\right)^2$$

$$= 1.425 \times 10^{-9} \text{ W} = 1.425 \text{ nW}$$

(c) What is $P_{received}$ of the SAM site due to the jammer transmission, i.e. the noise power? Hint: Use Friis. $P_R =$ 21.62 nW

The jamming J: Friis again, from your jammer over its own 75 km, into the same receive antenna ($G_R = 3$).

$$P_R = (2000)(20)(3)\left(\frac{0.4}{4\pi(75{,}000)}\right)^2$$

$$= 2.162 \times 10^{-8} \text{ W} = 21.62 \text{ nW}$$

(d) What is the SNR at the SAM site? SNR = .0659 > .06, ineffective!

$$SNR = \frac{S}{J} = \frac{1.425 \text{ nW}}{21.62 \text{ nW}} = 0.0659$$

The sheet's row gives the same, km over km:

$$SNR_{\text{comm}} = \frac{(1000)(3)(75)^2}{(2000)(20)(80)^2} = 0.0659$$

$0.0659 \geqslant 0.06$: the SAM site still processes its link, so the jamming is not effective

2. An adversary parabolic antenna at sea level is scanning the area for your aircraft flying at 30,000 feet MSL. Jamming seems like a good idea, so you turn on your jamming equipment. The parameters for the ground antenna and your jamming equipment are given below. If the ground antenna needs a signal to noise ratio of 0.01 to process and receive information about your aircraft, is your jamming effective *at the max LOS range*?

Ground Antenna	**Your jamming equipment**
Power transmitted = 20 kW	Power transmitted = 200 W
Transmit Antenna Gain = 2500	Transmit Antenna Gain = 10
Frequency = 9 GHz	RCS = 3 m^2

(a) What is the max LOS range? R_{LOS} = 394.37 km

The antenna is at sea level, so its term is zero:
$R_{LOS,mi} = \sqrt{2(30{,}000)} + \sqrt{2(0)} = 244.95$ mi
244.95 mi × 1.61 km/mi = 394.37 km

(b) What is $P_{received}$ of the transmitting ground antenna without jamming, i.e. the signal power? Hint: Use Radar Equation. P_R = 8.68 aW

The echo is two-way: the radar range equation, at R = 394,370 m. $\lambda = c/f = 0.03333$ m

$$P_R = \frac{P_T G_T^2 (RCS) \lambda^2}{(4\pi)^3 R^4}$$

$$= \frac{(20{,}000)(2500)^2(3)(0.03333)^2}{(4\pi)^3(394{,}370)^4}$$

$= 8.68 \times 10^{-18}$ W = 8.68 aW
(Rounding λ to 0.0333 m gives 8.66 aW.)

(c) What is $P_{received}$ of the transmitting ground antenna due to the jammer transmission, i.e. the noise power? Hint: Use Friis. P_R = 226 pW

The jamming is one-way: Friis from your jammer into the ground antenna, whose gain is the receive gain here, G_R = 2500.

$$P_R = (200)(10)(2500)\left(\frac{0.03333}{4\pi(394{,}370)}\right)^2$$

$= 2.26 \times 10^{-10}$ W = 226 pW

(d) What is the SNR at the transmitting ground antenna, i.e. the signal-to-jammer ratio S/J?

SNR = 38.4×10^{-9}, effective!

$$SNR = \frac{S}{J} = \frac{8.68 \text{ aW}}{226 \text{ pW}} = 3.84 \times 10^{-8}$$

The sheet's row gives the same (jammer on the target, so one R, in meters):

$$SNR_{\text{rad}} = \frac{(20{,}000)(2500)(3)}{(200)(10)(4\pi)(394{,}370)^2} = 3.84 \times 10^{-8}$$

$38.4 \times 10^{-9} < 0.01$: the ground antenna cannot process the echo, so the jamming is effective

3. A fire control RADAR at sea level is tracking your aircraft, which is flying at 15,000 feet MSL. Jamming seems like a good idea, so you turn on the jamming equipment your aircraft carries. The parameters for the RADAR and your aircraft are given below. The RADAR needs a signal to noise ratio of 1.5 to detect your aircraft.

Fire Control RADAR	**Your aircraft**
Power transmitted = 450 kW	Jammer power transmitted = 15 W
Transmit Antenna Gain = 4200	Jammer Transmit Antenna Gain = 2
Frequency = 5.5 GHz	RCS = 12 m^2

(a) What is the burn-through range, i.e. the range at which the SNR at the RADAR reaches the SNR it needs?

R_{BT} = 6.33 km

The jammer is on the target, so one R serves both paths: set the sheet's SNR_{rad} equal to SNR_{min} and solve for R.

$$R_{BT} = \sqrt{\frac{P_T\, G_T\, (RCS)}{P_{T,jam}\, G_{T,jam}\, 4\pi\, SNR_{\text{min}}}}$$

$$= \sqrt{\frac{(450{,}000)(4200)(12)}{(15)(2)(4\pi)(1.5)}} = \sqrt{4.011 \times 10^7}$$

= 6,333 m = 6.33 km

Meters, because the RCS is in m^2. The wavelength cancels, so the frequency is not needed.

(b) You are never closer to the RADAR than your altitude. Can the RADAR ever burn through your jamming?

Answer = 6.33 > 4.58 km, Yes

Closest approach, directly over the RADAR:

15,000 ft × 0.305 m/ft = 4,575 m = 4.58 km

R_{BT} = 6.33 km > 4.58 km: yes. A jammed RADAR detects only inside R_{BT}, and your range can fall inside it. Beyond 6.33 km the jamming hides you.

Had R_{BT} come out smaller than your altitude, the RADAR could never burn through.