Quiz #2
ECE 816 Spring Quarter 2007
April 18th, 2007

A radar system measures backscattering at 1 GHz from a random medium.

The radar system uses an antenna with a gain of 30 dBi in the direction of the random medium, with corresponding half power beamwidths of 0.1 radians (5.7 degrees) in both the elevation and azimuth planes.

The random medium exists in a thin layer between range distances of 4995 m to 5005 m from the radar.

The random medium is known to have a backscattering cross section per unit volume of $\rho\langle\sigma_b\rangle = 3\times10^{-6}$ per meter and an extinction cross section per unit volume of $\rho\langle\sigma_t\rangle = 3\times10^{-5}$ per meter. The radar system transmits a 1 kW of power.

(a) Find the expected value of the power received.

From the "narrow beam" approximation in the book for backscattering (eqn 4-19) we have $\frac{\langle P_R\rangle}{P_t} = (2.855\times10^{-4})\lambda^2G^2\theta_1\phi_1\int_{4995}^{(5005)}\frac{\rho\langle\sigma_b\rangle e^{-2\gamma}}{R^2}dR$ For $\lambda = 0.3$ m, $G = 1000$, we get

$$\frac{\langle P_R\rangle}{P_t} = (2.855\times10^{-4})(0.09)10^6(0.01)\int_{4995}^{(5005)}\frac{(3\times10^{-6})e^{-2\gamma}}{R^2}dR$$

Now approximate $\frac{1}{R^2}$ in integral as $\frac{1}{(5000)^2}$ and note $e^{-2\gamma} = e^{-2(3\times10^{-5})(R-4995)}\approx 1$.

Final answer: $\langle P_R\rangle = 10^3((2.855\times10^{-4})(0.09)10^6(0.01))\frac{(3\times10^{-6})}{5000^2}(10) = 0.308$ nWatts or -95.1 dB,watt.

(b) Find the Doppler shift (in Hz) observed by the radar if the random medium moves at a velocity of 10 m/s in the along range direction (i.e. moving away from the radar.)

Basic Doppler shift equation: $\frac{\omega}{\omega_0} = -\left((\hat{i}-\hat{O})\cdot\frac{\overline{U}}{c}\right) = -\left(\hat{i}\cdot2\frac{\overline{U}}{c}\right)$ for backscattering. Here we have $\omega = -2(2\pi\times10^9)\frac{10}{3\times10^8} = -418.9$ rads/s or 66.67 Hz.