7/10

7+7+7 = 21/25

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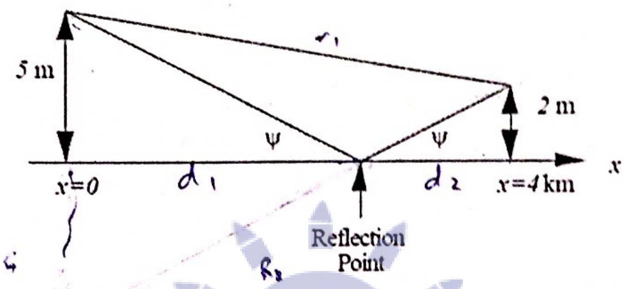
EE 407 **Second Exam** **Tuesday 26/4/2015**

Q1 (10 pts.) A **radar** antenna is mounted on a 5 m mast and tracks a point target at 4 km. The target is 2 m above the surface and the wavelength is 0.2 m. (a) Find the location of the reflection point on the x axis and the grazing angle ψ. (b) Calculate the path gain factor F in dB. (c) Plot the received power relative to free space as a function of the target height between 0 and 60 m.
(Assume flat earth and reflection coefficient of Γ = -1.)



(a)

$$\frac{5}{d_1} = \frac{2}{d_2} \quad , \quad d_2 = 4000 - d_1$$

$$2d_1 = 20000 - 5d_1 \Rightarrow d_1 = \frac{20000}{7} = \boxed{2857.1\ m}$$

4

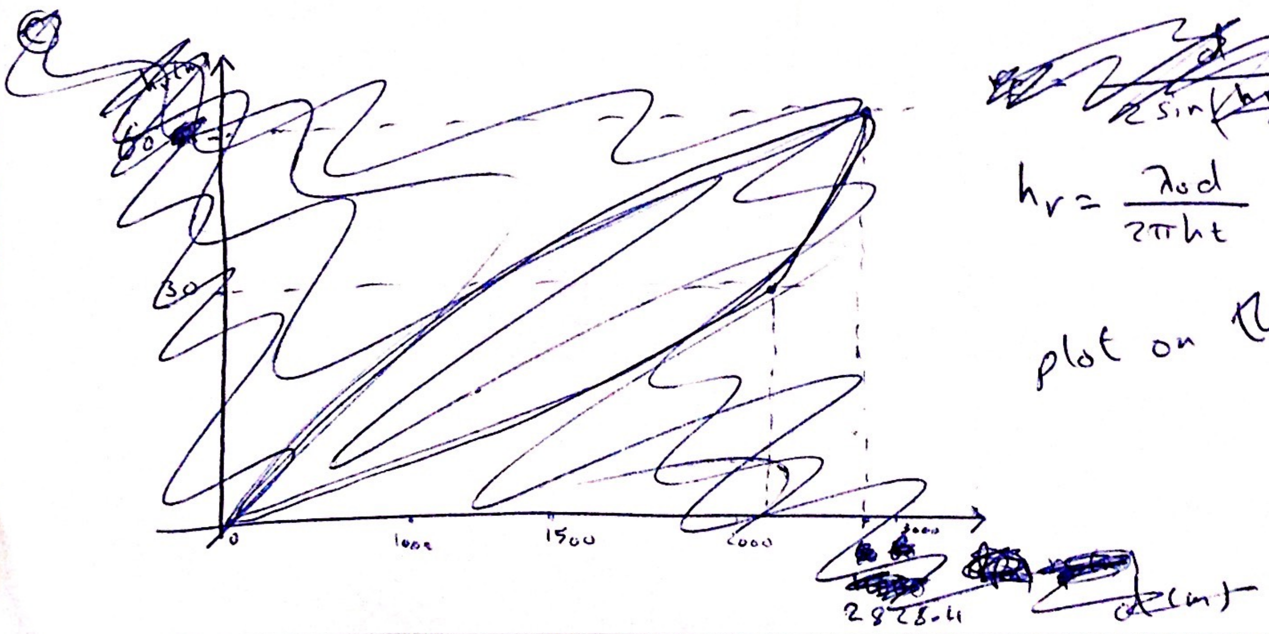
~~cos~~ $\tan\psi = \frac{5}{d_1} \Rightarrow \psi = \tan^{-1}\left(\frac{5}{2857.1}\right) \approx 0.1°$

(b) $F = 2\sin\left(\frac{\Delta\varphi}{2}\right)$, $\Delta\varphi = \frac{2\beta h_t h_r}{d} = \frac{4\pi h_t h_r}{\lambda d} = \frac{4\pi \times 5 \times 2}{0.2 \times 4000} = 0.157$

3

$\Rightarrow F = 0.157 \Rightarrow F(dB) = \underset{20}{10} \log\left(\frac{0.157}{2}\right) = \underset{-16}{-8\ dB}$ 9

(c)



~~$2\sin\left(\frac{h_r \times 2\pi h_t}{\lambda_o d}\right)$~~

$$h_r = \frac{\lambda_o d}{2\pi h_t} \sin^{-1}\left(\frac{d}{2r_f}\right)$$

plot on the back

Q2 (7 pts.) A communication link operates at 8 MHz with low gain antennas near the ground. The following parameters hold: $Pt = 5$ W; $Gt = Gr = 1$; ground parameters: $\varepsilon_r = 12$ and $\sigma = 5\times10^{-3}$ S/m.

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(a) Find the received power at the maximum flat Earth range.

(b) Find the received power at half the distance in part (a).

(a) $$d_{max}\text{(for flat earth)} = \frac{50}{(f_{MHz})^{\frac{1}{3}}} = 25 \text{ miles} = 40225 \text{ m}$$

$$P = \frac{\beta_o\ d}{2\sqrt{\varepsilon_r^2 + \left(\frac{\sigma}{\omega\varepsilon_o}\right)^2}} = \frac{2\pi \times 40225}{\frac{2c}{f} \times \sqrt{(12)^2 + \left(\frac{5\times10^{-3}}{2\pi f\varepsilon_o}\right)^2}} = 204.9$$

$$\Rightarrow |A_s| \approx 0.002 \text{ (from graph)}$$

⑤

$$P_{rec} = 4 P_{ro} |A_s|^2 = 4\times5\times1\times1\times\left(\frac{\frac{c}{f}}{4\pi\times d}\right)^2 \times (0.002)^2$$

$$= 4.4\times10^{-13} \text{ W} = -123.6 \text{ dBW}$$

(b) $$d = \frac{d_{max}}{2} = 20112.5$$

$$P_{new} = P_{old} \times \frac{20112.5}{40225} = 102.45$$

$$|A_s| \approx 0.004 \text{ (from graph)}$$

②

$$P_{rec} = 4\times5\times1\times1\times\left(\frac{\frac{c}{f}}{4\pi d}\right)^2 \times (0.004)^2 = 7.04\times10^{-12} \text{ W}$$

$$= -111.5 \text{ dB}$$

Q3 (8 pts.) A communication broadcasting system is to be established covering a distance of 6000 km using reflection from the ionosphere in two skips each 3000 km long. Assume the reflection takes place at a height of 300 km, and the electron density at this height is $5\times10^{11}/m^3$:

[illegible]

(a) Find the angle of incidence ψ_i and the launch angle Δ that should be used.
(b) What is the maximum usable frequency?

(R = 6370 km, R_e = 4/3R)

ⓐ $\theta = \frac{d_{skip}/2}{R_e} = \frac{1500}{\frac{4}{3}\times 6370} = 0.18 \text{ rad} \quad \angle 10.3^\circ$ ✓

$$\frac{1 + h'/R_e - \cos\theta}{\sin\theta} = \frac{1}{\tan\psi_i} \rightarrow \boxed{\psi_i = 73.95^\circ}$$ ✓

④

$$\Delta = \frac{\pi}{2} - \psi_i - \theta = \boxed{9\cancel{5}.75^\circ}$$

ⓑ $MUF = 9\sqrt{N_{emax}} \cdot \sec\psi_i$

③

$$= 9 \times \sqrt{5\times10^{11}} \times \sec(73.95^\circ) = \boxed{23.18 \text{ MHz}}$$