EEE 334 Semester 2 2016

Question 1

a.

1) PSR. Detects targets with a given RCS gives range, angle and speed informationvia processing
2) SSR. Cooperative radar system. Transducer on target Txs info on location etc
3) Co-located Tx/Rx antennas
4) Tx and RX antennas at different locations

4 Marks

First need to calculate PRF which is limited by max range

$$PRF = \frac{c}{2R_{\max}} = \frac{3\times10^8}{2\times490} = 306Hz$$

Duty cycle is $\frac{\tau}{T}$ or (pulse duration)/ (pulse repetition interval) $= 140\times10^{-6}\times306 = 4.28\,\%$

Mean power = (peak power).(duty cycle) = $56kW\times4.8 = 2.4kW$

Power gain, $G = \frac{4\pi}{\Delta\theta\Delta\phi}$

$$\Delta\theta = \frac{\lambda}{h\times\eta} = \frac{3\times10^8/1.3\times10^9}{6.9\times0.707} = 0.047rad \text{ or 2.7 degrees}$$

$$\Delta\phi = \frac{\lambda}{w\times\eta} = \frac{3\times10^8/1.3\times10^9}{11.9\times0.707} = 0.027rad \text{ or 1.57 degrees}$$

So gain $G = \frac{4\pi}{0.027\times0.047} = 9820$ or 40dB

Rotation rate = 5rpm = $\frac{360^0}{(6^0/5)\sec} = 30^0/s$

A point target is therefore illuminated for $\frac{\Delta\phi^0}{30^0/s} = \frac{1.57}{30} = 52.3mS$

Number of hits = PRF . (illumination time) = $0.0523\times306 = 16$

Doppler resolution = 1/illumination time = 1/0.0523 = 19Hz

10 Marks

Doppler frequency given by

$$f := f_0 \cdot 2 \cdot \frac{Vr}{c}$$

f0 = Tx frequency
Vr = relative velocity

CASE B: $Vr := -130 - (-80)$ $\quad Vr = -50$ km/h or 13.9 m/s

$$fb := \frac{2 \cdot 13.9 \cdot 10^{10}}{3 \cdot 10^{8}} = 926.667 \text{ Hz}$$

CASE C: $Vr := 60 - (-80)$ $\quad Vr = 140$ km/h or 38.9 m/s

$$fc := \frac{2 \cdot 38.9 \cdot 10^{10}}{3 \cdot 10^{8}} = 2.593 \times 10^{3} \text{ Hz}$$

CASE D: $Vr := -100 \cdot \cos\left(\frac{\pi}{4}\right) - (-80)$ $\quad Vr = 9.289$ km/h or 2.58 m/s

$$fd := \frac{2 \cdot 2.58 \cdot 10^{10}}{3 \cdot 10^{8}} = 172 \text{ Hz}$$

CASE E: $Vr := 100 \cdot \cos\left(\frac{\pi}{4}\right) - (-80)$ $\quad Vr = 150.711$ km/h or 41.8 m/s

$$fe := \frac{2 \cdot 41.8 \cdot 10^{10}}{3 \cdot 10^{8}} = 2.787 \times 10^{3} \text{ Hz}$$

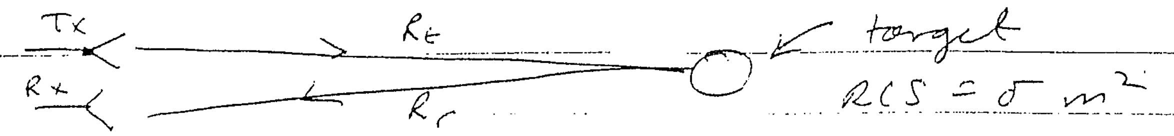
CASE F: $Vr := 0 - (-80)$ $\quad Vr = 80$

$$fd := \frac{2 \cdot 22.2 \cdot 10^{10}}{3 \cdot 10^{8}} = 1.48 \times 10^{3} \text{ Hz}$$

6Marks

2016

Q2 (A) radar range equation



Power density at target is

$$P_D = \frac{P_t}{4\pi R_t^2} G_t \qquad \begin{aligned} P_t &= \text{Tx power} \\ G_t &= \text{Tx antenna gain} \\ R_t &= \text{distance to target.} \end{aligned}$$

Power reradiated by target is

$$P_{RR} = P_D \sigma \qquad \sigma = \text{RCS of target in } m^2$$

Power density back at radar is

$$P_{RD} = \frac{P_{RR}}{4\pi R_r^2} = \frac{P_D \sigma}{4\pi R_r^2} = \frac{P_t G_t \sigma}{(4\pi)^2 (R_t R_r)^2}$$

for mono-static radar $R_t = R_r = R$ hence

$$P_{RD} = \frac{P_t G_t \sigma}{(4\pi R^2)^2}$$

Power intercepted by Rx antenna with effective aperture A_e is

$$P_R = P_{RD} A_e$$

Substituting $G_R = \frac{4\pi A_e}{\lambda^2}$ where G_R = Rx antenna gain

$$P_R = \frac{P_t G_t G_R \sigma \lambda^2}{(4\pi)^3 R^4}$$

Let total systems Losses be represented by L_s (< 1) to give

$$P_R = \frac{P_t G_t G_R \sigma \lambda^2 L_s}{(4\pi)^3 R^4}$$

Let N = average system noise power so that

$$SNR = \frac{P_R}{N} = \frac{P_t G_t G_R \sigma \lambda^2 L_s}{(4\pi)^3 N R^4}$$

or

$$R = \left[\frac{P_t G_t G_R \sigma \lambda^2 L_s}{(4\pi)^3 N . (SNR)}\right]^{1/4}$$

[6]

Q2 (B)

i) Approx beamwidth $\Delta = \frac{\lambda}{D}$ ← effective dimension of antenna in required plane.

At 9.4 GHz $\lambda = 0.032m$

$$\therefore \Delta\theta \simeq \frac{0.032}{3.4} \times \frac{180}{\pi} = 0.54^\circ$$ – elevation

$$\Delta\phi \simeq \frac{0.032}{0.75} \times \frac{180}{\pi} = 2.4^\circ$$ – azimuth

Antenna gain $G = \frac{4\pi A_e}{\lambda^2}$ ← effective area

$$= \frac{4\pi \times (3.4 \times 0.75)}{(0.032)^2}$$

$$= 31293 = \underline{45 dB}$$

[note: may also use the approximation

$$G \simeq \frac{41253}{\Delta\theta^\circ \Delta\phi^\circ} \rightarrow 45 dB$$

[4]

ii) use radar range equation (derived in part A but should know)

P_t = 40 dBW
$G_t G_R = G^2$ = 90 dB
σ = 0 dBm^2
λ^2 = −29.9 dBm^2
L_s = −5 dB
$1/(4\pi)^3$ = −33 dB
$1/N$ = +140 dBW^{-1}
$1/(SNR)$ = −13 dB

R^4_{max} = 189 dBm^4

put all values in dB and add OR convert to linear value and × and ÷

→ ÷ by 4 to give 47.3 dBm = $\underline{53.4 km}$

[5]

24/ 40f T

3/ Signal illuminated and detected by -20dB sidelobe giving total reduction in signal of 40dB.
But range reduced by 1/2 = -12 dBm⁴

→ Total increase in RCS is

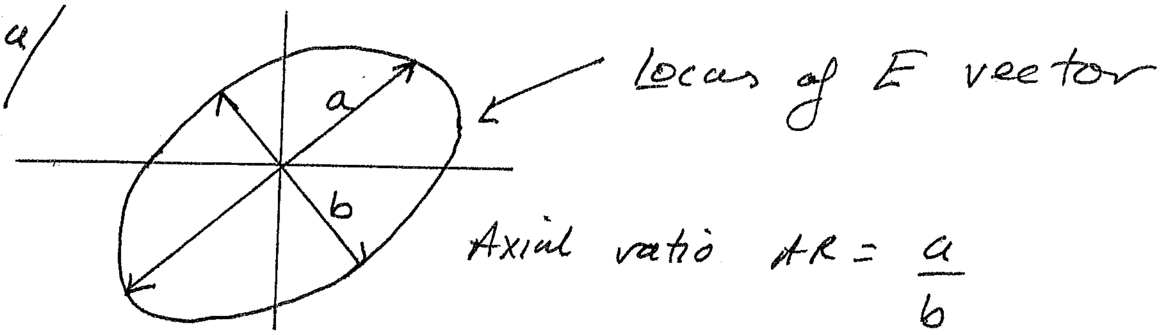
$$(40 - 12) = 28 \, dBm^2$$

$$\therefore \sigma' = \sigma_0 + 28 \quad dBm^2$$

$$= \underline{28 \, dBm^2 \text{ or } 631 \, m^2}$$

[5]

3a/



Axial ratio $AR = \frac{a}{b}$

Limits $1 \leq AR \leq \infty$

circular pol

linear pol

4

b/

Tx1 & Rx1 vertically polarised
Tx2 & Rx2 Horizontally "
signal from ~~R~~x1 received by Rx1
but not by Rx2
signal from Tx2 received by Rx2
but not Rx1
Hence can transmit 2 signals using same frequency and double capacity.
Can ~~also~~ also use RHC & LHC polarisation

4

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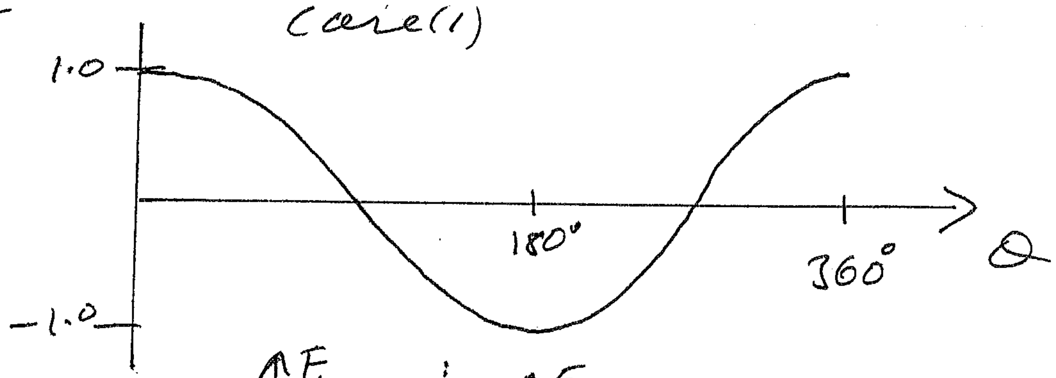
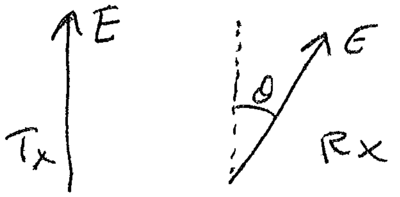
3c

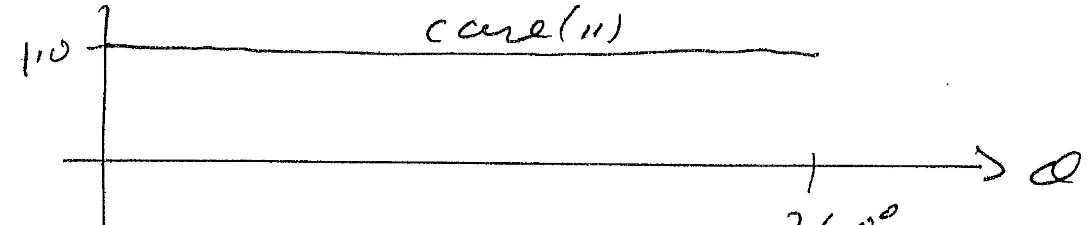
case(i)





Received signal $\propto \cos\theta$

case(ii)



Received signal constant.

(6)

3D $P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$

$f = 2.4\,\text{GHz} \Rightarrow \lambda = 0.125\,\text{m}$; $P_t = 5 \times 10^{-3}\,\text{W}$

$G_t = G_r = 1$; $R = 0.5\,\text{m}$

$\Rightarrow P_r = 5 \times 10^{-3} \times 1 \times 1 \times \left(\frac{0.125}{4 \times \pi \times 0.5}\right)^2 = 1.98 \times 10^{-6}\,\text{W}$

to get to dBm

$10 \times \log_{10}\left(\frac{1.98 \times 10^{-6}}{10^{-3}}\right)$ ← mW

$= \underline{-27\,\text{dBm}}$

(6)

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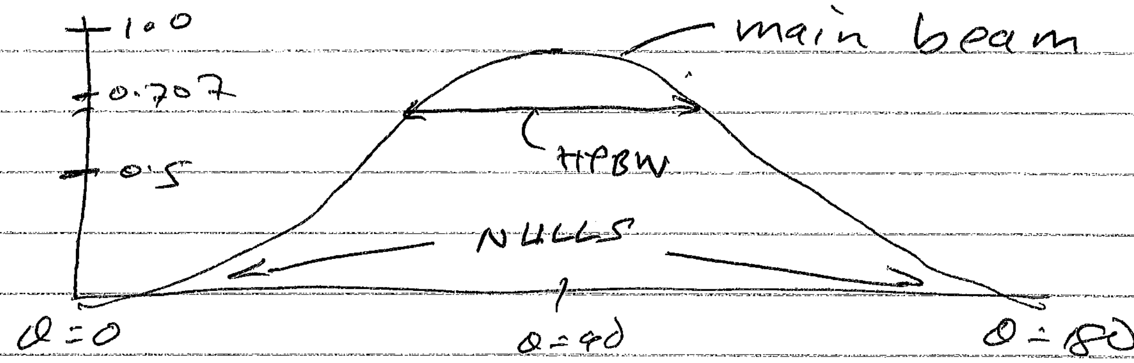
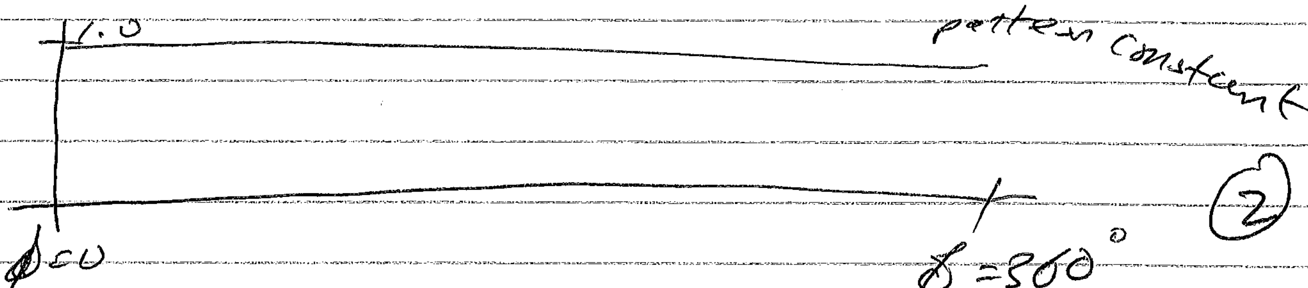
4a



b



(2)

c $\theta = 90°$, D $\theta = 0°$ + $\theta = 180°$ (2) + (2)

e we have $\int_0^{2\pi}\int_0^{\pi} D(\theta,\phi)\sin\theta \, d\theta \, d\phi = 4\pi$ str

$\therefore \int_0^{2\pi} d\phi \int_0^{\pi} D_0 \sin^3\theta \sin\theta \, d\theta = 4\pi$

$\therefore 2\pi D_0 \int_0^{\pi} \sin^4\theta \, d\theta = 4\pi$

$2\pi D_0 \left[\frac{3\theta}{8}\right]_0^{\pi} = 4\pi \rightarrow D_0 = 16/3\pi$ (6)

f) $P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$. $G_t = \frac{16}{3\pi}$ as lossless

$G_r = 1.0$, $P_t = 100\,W$, $R = 10^3\,m$, $\lambda = 0.3\,m$

$\therefore P_r = 100 \times \frac{16}{3\pi} \times 1 \times \left(\frac{0.3}{4\pi \times 10^3}\right)^2$ (4)

$= 9.7 \times 10^{-8}\,W$ or $97\,nW$