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Q1. a) i) Duty cycle $= \frac{\text{pulse length}}{\text{period}}$

$= \text{pulse length} \times PRF$

$= 1.5 \times 10^{-6} \times 480 = \underline{7.2 \times 10^{-4}}$

mean power $=$ peak power $\times$ duty cycle

$= 1.4 \times 10^{6} \times 7.2 \times 10^{-4} = \underline{1\,kW}$

2

b)

Target illuminated for $t = \frac{\Delta\theta°}{360°} \times$ period of rev

$= \frac{\Delta\theta}{360} \times \frac{1}{RPM/60}$ → to give rad/s

During this period number of pulses hitting target is

$n = t \times PRF$

$\therefore \quad n = \frac{\Delta\theta}{360} \times \frac{60}{RPM} \times PRF = \frac{\Delta\theta}{6} \frac{PRF}{RPM}$ 4

$\therefore \quad n = \frac{1.2}{6} \times \frac{480}{16} = 16$ pulses 1

Q1. a) cont

iii) Range resolution $= \Delta R = \frac{c\tau}{2}$

$= \frac{3\times10^{8} \times 1.5\times10^{-6}}{2} = \underline{225\ m}$

Doppler res $\sim 1/t$

and $t = \frac{1.2}{360} \times \frac{60}{6} = \underline{0.033\ s}$

$\Rightarrow$ Doppler res $= \underline{30\ Hz}$

unambiguous range $R_{max} = \frac{c}{2\times PRF}$

$= \frac{3\times10^{8}}{2\times480}$

$= \underline{312.5\ km}$

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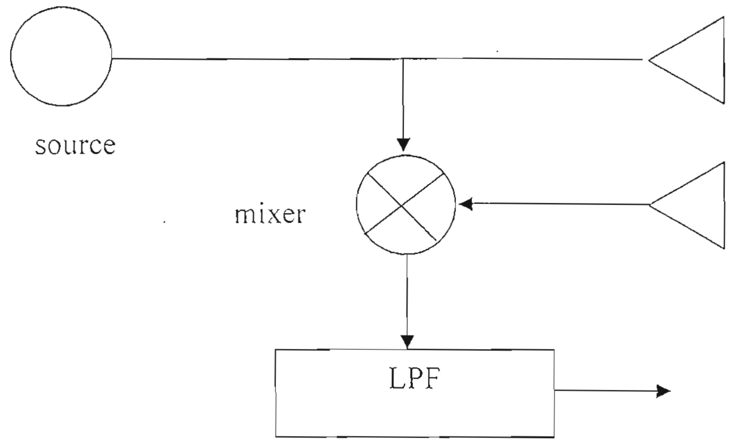
1b



Tx signal = $\cos(\omega_0 t)$

Rx signal = $B\cos(\omega_d t)$

At mixer Rx is multiplied by a signal with same frequency as Tx signal

Output from mixer is $S = B\cos(\omega_d t)\cos(\omega_0 t)$

Expand to give $S = \frac{B}{2}\left[\cos\left[(\omega_d - \omega_0)t\right] + \cos\left[(\omega_d + \omega_0)t\right]\right]$

Low-pass filtering leaves only difference term i.e. $\frac{B}{2}\cos(\omega_d - \omega_0)$ where Doppler frequency $\Delta\omega = \omega_d - \omega_0$

(4)

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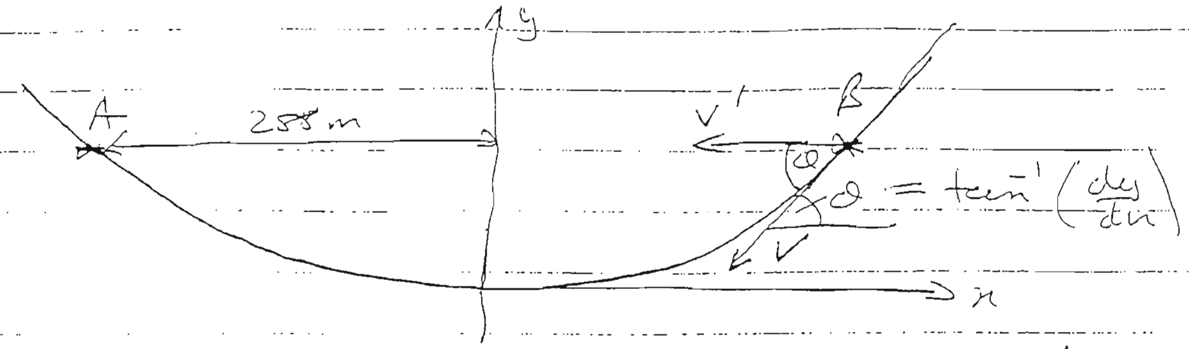

Gradient of road at point B is given by

$$\tan\theta = \frac{dy}{dx} = x/500$$

at $x = 288$ this gives $\tan\theta = 0.576$
$\Rightarrow \theta \simeq 30°$.

Component of B's velocity along boresight direction of radar is

$$V' = V\cos 30°$$

If $V' = 65$ mph then

$$V = 65/\cos 30° = 75\text{mph}$$

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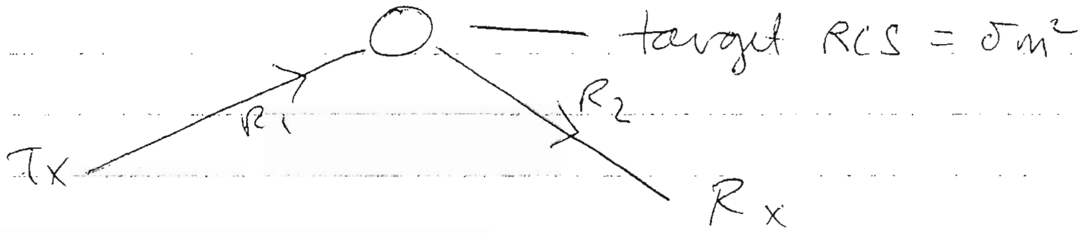
2.a) EEE 2012–13



Power density at target is

$$P_D = \frac{P_t G_t}{4\pi R_1^2}$$

P_t = Tx power
G_t = Tx antenna gain
R_1 = distance to target

Power radiated by target is

$$P_S = P_D \sigma \quad \rightarrow \sigma = \text{rcs in } m^2$$

Power density at Rx is

$$P_{RD} = \frac{P_S}{4\pi R_2^2} = \frac{P_D \sigma}{4\pi R_2^2} = \frac{P_t G_t \sigma}{(4\pi)^2 R_1^2 R_2^2}$$

Power intercepted by Rx antenna with effective area A_e is

$$P_R = P_{RD} A_e$$

using $G_R = \dfrac{4\pi A_e}{\lambda^2}$ gives

G_R = antenna gain Rx

$$P_R = \frac{P_t G_t G_R \sigma \lambda^2}{(4\pi)^3 R_1^2 R_2^2}$$

2 4) EEE

Let total system losses be represented by L_s (≤ 1) to give

$$P_R = \frac{P_t G_t G_R \sigma \lambda^2 L_s}{(4\pi)^3 R_1^2 R_2^2}$$

Let N = average system noise power so that

$$SNR = \frac{P_R}{N} = \frac{P_t G_t G_R \sigma \lambda^2 L_s}{(4\pi)^3 N R_1^2 R_2^2}$$

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

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Q 2. b/

$$P_r = \frac{P_t G_t G_r \sigma \lambda^2 L_s}{(4\pi)^3 R_1^2 R_2^2}$$

[from part a) but should know]

we have $P_t = 10^3$ W

$G_t = 3162$ (35dB)

$G_r = 10$ (10dB)

$\sigma = 2$

$\lambda^2 = (0.03)^2$

$L_s = 0.63$ (2dB Loss)

3, 4, 5 triangle gives $R_2 = 5$ km and $R_1 = 3$ km

$$\therefore P_r = \frac{1 \times 10^3 \times 10 \times 3162 \times 2.0 \times (0.03)^2 \times 0.63}{(4\pi)^3 \times 9 \times 10^6 \times 25 \times 10^6}$$

$$= \underline{\underline{8 \times 10^{-14} \text{ W}}}$$

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Q2 c)

First work out some basic values

$\lambda := \frac{0.3}{8}$ $\lambda = 0.038$ wavelength in metres

$Pt := 20000($ transmit power

$\sigma := 1.($ RCS in m^2

$Pj := 150($ jammer power

$Gt := 4($ radar main beam gain dB

$Gj := 3($ jammer antenna gain dB

$Gx := 1\zeta$ sidelobe gain dB

$Gj := 10^{\frac{Gj}{10}}$ $Gt := 10^{\frac{Gt}{10}}$ $Gx := 10^{\frac{Gx}{10}}$ convert gains to linear values

$Gj = 1 \times 10^{3}$ $Gt = 1 \times 10^{4}$ $Gx = 31.623$

$Rj := 10000($ distance from jammer to radar

$$R := \left(\frac{Pt \cdot Gt \cdot Gt \cdot Rj^{2} \cdot \sigma}{Pj \cdot Gj \cdot Gx \cdot 4 \cdot \pi}\right)^{\frac{1}{4}}$$ using equation for burnthrough range

$R = 4.28 \times 10^{3}$ metres

8 marks

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Q3

a

i. High gain dish antenna

ii. monopole, heated rear window antenna or similar

iii. Yagi

iv. Phased array with electronic scanning

v. passive linear array

(5)

3 b.For dipole

$\frac{\lambda}{2} = 1m$ so $\lambda = 2m$ using $c = f\lambda$ gives frequency = 150MHz, $R_L = 0.75\ Ohms$

current $I = \frac{V_s}{Z_g + Z_a} = \frac{100}{50 + 73 + j42.5} = 0.768\angle -19.1$ A

Pdiss =Ploss = $\frac{I^2 R_L}{2} = 221$mW

Prad= $\frac{I^2 R_R}{2} = 21.54$W

Eff= $\frac{R_R}{R_R + R_L} = 98.9\%$

(5)

For monopole

$\frac{\lambda}{4} = 1m\ so\ \lambda = 4m$ giving frequency of 75MHz, $R_L = 0.5\ Ohms$

Impedance of monopole is half that of dipole, so

current = $\frac{100}{50 + \frac{(73 + j\cdot 42.5)}{2}} = 1.09 - 0.268i$ = 1.122 angle -13.8 A

Pdiss =Ploss = $\frac{I^2 R_L}{2} = 314$mW

Prad= $\frac{I^2 R_R}{2} = 23$W

Eff= $\frac{R_R}{R_R + R_L} = 98.6\%$

(5)

3 c.

Total radiated power given by

$$\int_0^{2\cdot\pi}\int_0^{\frac{\pi}{6}} 1\cdot\sin(\theta)\,d\theta\,d\phi + \int_0^{2\cdot\pi}\int_{\frac{\pi}{6}}^{\pi} 0.2\cdot\sin(\theta)\,d\theta\,d\phi$$

$$P1 := \int_0^{2\cdot\pi}\int_0^{\frac{\pi}{6}} 1\cdot\sin(\theta)\,d\theta\,d\phi = 0.842 \quad + \quad P2 := \int_0^{2\cdot\pi}\int_{\frac{\pi}{6}}^{\pi} 0.2\cdot\sin(\theta)\,d\theta\,d\phi = 2.345$$

P=P1+P2 = 3.187. Directivity = $\frac{4\pi U_{max}}{P} = \frac{4\pi.1}{3.187} = 3.9$ or 6dB

(5)

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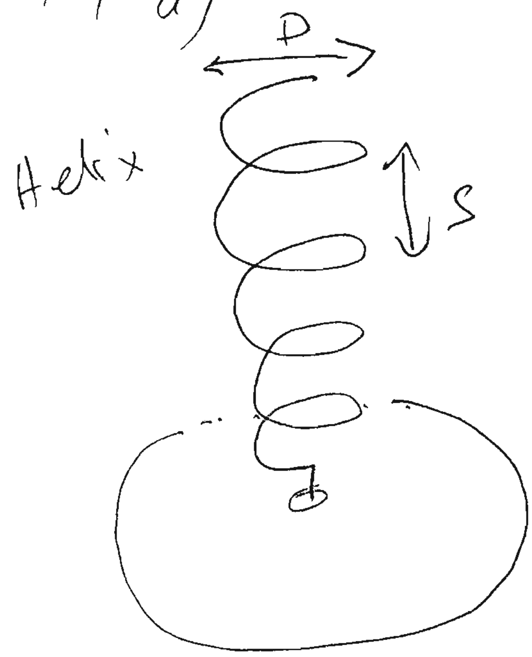
Q4 a)



general properties

N = number of turns

D = diameter

S = spacing between turns

pitch angle $\alpha = \tan^{-1}\left(\frac{S}{C}\right)$

when $C = \pi D$ = circumference

For axial mode helix (radiation along axis) we have

$$3/4 < C/\lambda < 4/3$$

and $\alpha \simeq 12^\circ - 14^\circ$

For normal mode (radiation normal to axis)

total length of helix $\ll \lambda$

In both cases, the helix radiates CP.

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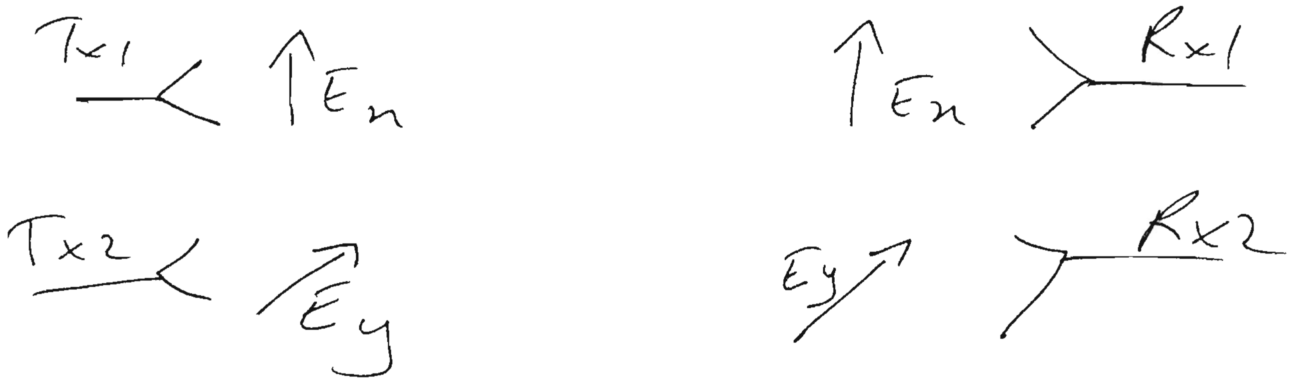
4 b) Polarisation diversity.



Tx1 and Rx1 vertically polarised
Tx2 and Rx2 Horizontally "

Signal from Tx1 received by Rx1
But <u>not</u> received by Rx2

Signal from Tx2 received by Rx2
but <u>NOT</u> by Rx1

Hence can transmit 2 signals using same frequency and double capacity.

Can also use LHC + RHC pol

4

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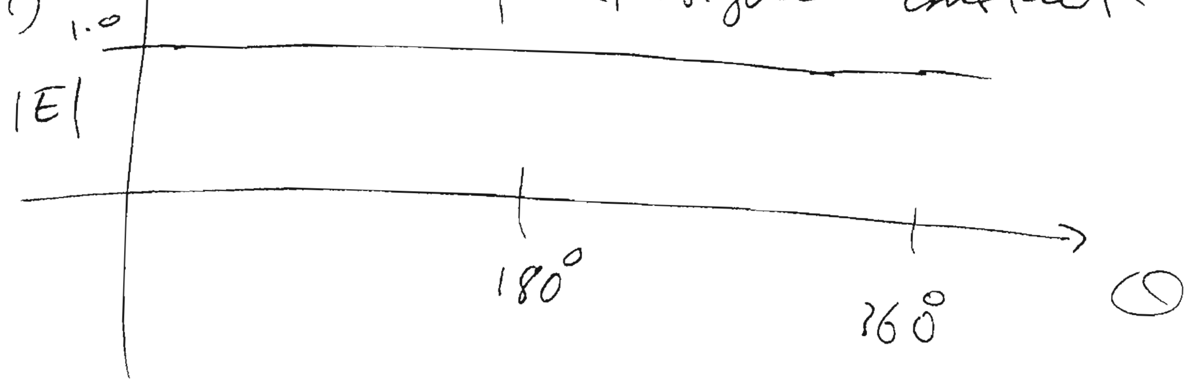
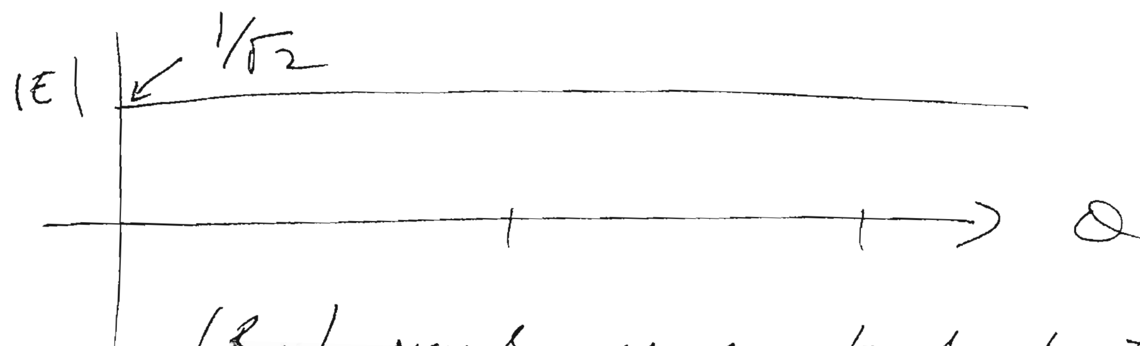
4 c) i) |Rx| signal constant



ii)



|Rx| signal is constant, but magnitude $\frac{1}{\sqrt{2}}$ that of case (i)

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4 d)

Solution is based on Friis transmission equation

$$Pr := Pt \cdot Gt \cdot Gr \cdot \left(\frac{\lambda}{4 \cdot \pi \cdot R}\right)^2$$

A 11.8GHz satellite comms link consists of a 4.5m diameter dish transmit antenna with an aperture efficiency of 0.75, and a receive dish antenna of 1.8m diameter with an aperture efficiency of 0.5. If the distance between the link is 35787km and the transmit power is 80W, calculate the magnitude of the received power.

First calculate some addtional parameters from given information

wavelength $\lambda := \frac{3 \cdot 10^8}{11.8 \cdot 10^9}$ $\lambda = 0.025$ metres

Tx power $Pt := 8C$ Watts

Range $R := 3578 \cdot 10^3$ metres

Diamiter of TX dish $Dt := 4.8$ $\eta t := 0.7$ TX efficiency

Diamiter of RX dish $Dr := 1.8$ $\eta r := 0.5$ RX efficiency

Effective area of TX antenna $At := \left(\frac{Dt}{2}\right)^2 \cdot \pi \cdot \eta t$ $At = 13.572$

Gain of TX antenna $Gt := \frac{4 \cdot \pi \cdot At}{\lambda^2}$ $Gt = 2.639 \times 10^5$

Effective area of RX antenna $Ar := \left(\frac{Dr}{2}\right)^2 \cdot \pi \cdot \eta r$ $Ar = 1.272$

Gain of RX antenna $Gr := \frac{4 \cdot \pi \cdot Ar}{\lambda^2}$ $Gr = 2.474 \times 10^4$

Therefore received power is

$$Pr := Pt \cdot Gt \cdot Gr \cdot \left(\frac{\lambda}{4 \cdot \pi \cdot R}\right)^2$$ $Pr = 1.669 \times 10^{-7}$ Watts

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