Practice Questions 5

Q.1 Answer any 5 of 6 multi-choice questions **(1 X 5=5 Marks)**

Selectmost appropriate choice(s) from given options. Write an explanation for the same.

(i) A pulsed radar uses 8 μs transmit pulse coded with 4 bit Barker code. Pulse Repetition Frequency (PRF) is 10 KHz, Peak power is 100 kW. What is the average transmit power?

(a) 2 kW (b) 8 kW (c) 4 kW (d) 800 W

(ii) What will be range resolution with the system having parameters given in Q1 (i)?

(a) 150m (b) 1.2km (c) 300m (d) 120m

(iii) Noise temperature of 29000K over a bandwidth of 1 kHz, would correspond to the approximate noise power of

Boltzmann’s constant = 1.38 X 10-23 J.K-1…

(a)1.38 X 10 -19 W (b)1.38 X 10-20 mW (c) 4.002 X 10-20 W (d) 4.002 X 10-17W

(iv) An amplifier has two-stages. The noise figure and gains of individual stages are (F1=1.8, G1= 100) and (F2=2, G1=300). What will be noise figure of the cascaded (stage1 followed by stage2) amplifier?

(a) 1.81 (b) 1.8033 (c) 1.82 (d) 2.18

(v) An lossless omni-directional antenna radiates ‘π’kW (3.1415 kW approx.) power. What is the power density ( in watts per m-2) at a distance of 5 km?

(a) 1 mW·m-2 (b) 10 µW·m-2 (c) 1µW·m-2 (d) 10 mWm-2

(vi) Power of 30 mW is ‘xxx’ dBm. So xxx= ?

(a) 1000dBm (b) 4.77 dBm (c) 1.477 dBm (d) 14.77 dBm

Q.2 (1× 5 = 5 Marks)

Provide short (one or two sentences) explanation for the following: **(Reason any 5)**

(i) The range resolution of the radar depends on the band-width irrespective to the mode (pulsed or continuous); True or False?

(ii) VHF Omni-directional Range (VoR) systems provide bearing (angular position/ direction) of the aircraft from the station. In order to find its own position, signals from which other instruments are required? Options: DME (gives slant range), Altimeter (gives altitude), Another VoR, ILS (gives guidance to maintain angle of glide). Explain with only diagram or diagram with a couple of lines.

(iii) It is said that the vacuum devices with curvilinear motion of charge particles (magnetrons, carcinotron) can produce higher energy (or power) compared to the devices with linear motion (Triode, TWT etc) at the same voltage levels. Comment on the claim/ give possible explanation.

(iv) Delay jamming technique involves detecting the radar transmission and re-transmitting the replica of radar pulses with random delays. How does this technique give false indication of the target range?

(v) A continuous wave radar ‘ranging system’ transmits a fixed frequency sine wave with wavelength ‘λ’. Echo received by this radar, is down converted to the base band using the part of the transmitted signal as local oscillator (LO). What is the maximum interval over which this system offers unambiguous range detection?

(vi) The power amplifiers are often operated in class ‘C’, ‘D’, ‘E’, etc. Whereas, the low noise Amplifiers (LNA) in the receiver front end always in class ‘A’, B’ or ‘AB’. Why?

(Hint: C, D … have better power efficiency, whereas A,B, AB… have low distortions)

Q3 (6 Marks)

A pulsed Doppler radar operating at 15GHz uses 3 pulse repetition frequencies (PRFs), namely 10kHz, 15 kHz and 20 kHz. It detects 3 targets, A, B, and C. The receiver performs complex (In phase and quadrature) sampling followed by Doppler frequency measurement. Then it presents the data with The range and the velocities of the targets are given in following table.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | PRF 10 kHz | | PRF 15 kHz | | PRF 20 kHz | |
|  | **Range** | **Velocity** | **Range** | **Velocity** | **Range** | **Velocity** |
| Target A | 9km | -20ms-1 | 9km | -20ms-1 | 1.5km | -20ms-1 |
| Target B | 4 km | 30ms-1 | 4 km | 30ms-1 | 4 km | 30ms-1 |
| Target C | 5km | +20ms-1 | 5km | +70ms-1 | 5km | -80ms-1 |

(a)Find the unambiguous range and unambiguous velocity for each of the PRF? (1X3=3)

(b) Find the correct range and velocity of each of the targets A, B, C. (1X 3= 3)

Q4 (6 Marks)

**Beam steering with phased array antenna**

A two dimensional array of the antenna is set up on X-Y plane. This array has 63 elements (arranged in 7X9 formation). All the elements are located on the grid of 1cm. This means that the individual element locations are (0,0), (0,1), (1,1) etc.(in cm) and fills up all the locations (i,j) where -3< i <+3 and -4< j <+4. The radiation frequency is 15 GHz.

(a) When the beam is pointing at zenith (in the direction of +ve Z axis) what is the beam width of the antenna beam in X-Z plane and in Y-Z plane? (2 marks)

(b) In order to tilt the beam at -100 with respect to positive ‘Z’ axis (making angle of 800 with positive x axis) in X-Z plane. Take phase of element at (0,0) as reference (0 deg, say). What will be the phase to the antenna element (1,0) and (0,-2) (mention leading of lagging/ sign)

1. marks)

(c)For the beam tilt in (b) is increased to -200 (making angle of 700 with positive x axis) in X-Z plane calculate the phases of the same elements (-1,0) and (2,2) (2 marks)

Z

100

P(b)

Y

X

Fig.3

Q5 (6 Marks)

**Matched filter and Pulse Compression**

**(a)** What is a matched filter? What purpose does it serve in radar receivers? (1)

The range resolution of the radar can be increased by performing ‘bi-phase’ coding in the transmit pulse. The received signal is processed by performing correlation with the same bi-phase sequence of the transmit code. This is also called pulse ‘pulse compression’.

Consider a 10 microsecond pulse is coded with a 5 bit code: “ +1,-1,+1,+1,+1”

(b) Draw transmit-code showing schematic waveform of bi-phase code (1)

(c) What will be the range resolution of this system? (1)

(d) What will be the nearest distance whose echo can be processed? (1)

(also known as blind range)

(e) Show the correlation output when the echo is correlated in the base-band signal

(in other words, draw the autocorrelation function). And show the range side-lobes. (1)

(f) What will be the ratio of range side-lobe magnitude compared to the main lobe?

(1)

**EE 602 (2018) End Semester Examination (Answers)**

Q.1 Answer any 5 of 6 multi-choice questions **(1 X 5=5 Marks)**

(i) - (b)

PRP = 1/PRF =1/10000 = 100µs

Average power = (PW/PRP) X Pt 🡺 (8/100) (μs) X 100 (kW)= 8kW.

(ii)-(c)

After the application of the Barker code, resolution pulse-width is 2 µs

Resolution = (c XPW)/2 = (3X108 X 2 X10-6)/2= 300m

(iii)-(d)

Noise Power = 1.38 X 10-23 X 2900 X 1000 = 4.002 X 10-17W

(iv)-(a)



(v)-(b)

Gain of Omni-antenna=1. The power density at range *(R)* 

(vi)-(d)

10 log (30mW/1mW)= 14.77dBm.

Q.2 (1× 5 = 5 Marks)

Provide short (one or two sentences) explanation for the following: **(Reason any 5)**

1. True. For Pulse radar, Range Resolution is cτ/2= c/2ΔF; also for FMCW radars.

1. VoR, DME and altimeter Or 2 VoRs and Altimeter Both answers are OK.

(Even one of the two answers without altimeter is OK; 2-D positioning is possible that way!)

From Altimeter

N

E

Aircraft Location

DME/VoR station

From Altimeter

From DME

Angle

From VoR

DME/VoR station

Aircraft Location

Angle

From VoR1

DME/VoR station

Aircraft Location

N

Angle

From VoR2

N

E

1. The particles get accelerated due to the voltage difference between cathode and Anode (or collector). In curvilinear devices, magnetic field adds to the electron acceleration thereby attaining high velocity or energy/ power.
2. The radar (under jamming attack) receives these re-transmitted pulses and estimates the target range on the round-trip time. This estimation is erroneous as the delays are not related to target(s).
3. Single frequency CW radar on direct down-conversion, can give unambiguous range estimation only for the round trip time path difference differs by ‘λ’. Hence the length of the range interval is ‘λ /2’. In other words, this radar can detect the range unambiguously between ‘R’ and ‘R+ λ /2’, for any R.
4. Radar transmitters radiate high power (in kWatts). Power efficiency is most important parameter as otherwise power consumption is increased unreasonably making it uneconomical. On the other hand, the receiver is expected to extract the maximum features from the signal. Therefore, the amplifiers are operated in classes with these properties. ( any equivalent argument may be given credit)

Q3 (6 Marks)

(a)Find the unambiguous range and unambiguous velocity for each of the PRF?

Unambiguous range and Velocity   Respectively

PRF of 10 KHz: *Run*= 15 km. *Vun*= ±50ms-1

PRF of 15 KHz: *Run*= 10 km. *Vun*= ±75ms-1

PRF of 20 KHz: *Run*= 7.5 km. *Vun*= ±100ms-1 3 marks

(b) Find the correct range and velocity of each of the targets A, B, C.

Range Ambiguity leads to mapping of *R* > *Run* as *R* mod *Run*

Velocity ambiguity can better be explained by following diagram. Frequencies in regions of the same colour get mapped fundamental band of –*fmax*/2 to +*fmax*/2.

-fmax/2 0 +fmax/2

Target A: 9 km and -20ms-1 (shows different reading due to the range ambiguity)

Target B: 4 km and 30ms-1 (consistent readings: range, velocity in ‘unambiguous range’)

Target C: 5km and -80ms-1: Velocity is out of Unambiguous range for PRF1 and PRF2, gets mapped. As illustrated above

Half mark for each correct answer, no weightage to explanation

Q4 (6 Marks)

1. Swath?

The beam spreads from 45-7=380 to 45+7=520

15,000(tan 520-tan 380)= 19199.12-11719.28 = 7479.84~(7.4 km) (2 marks)

1. Min and Max Range-bin dimension:

The range-resolution due to PW=0.25 μs in the radial direction is 37.5m

Minimum range-bin size will occur in the region far from the aircraft track.

37.5/ sin (520) =47.58m

Maximum range-bin size will occur in the region near to the aircraft track.

37.5/ sin (380) = 60.9m (1 X2 = 2 Marks)

Extra Info (Not asked in the paper)

This arrangement has 142 range-bins= (1/37.5){(15000/cos520)- (15000/cos380)}

(c) If the air craft collects the data for the period of 300ms, what is the angular resolution (in azimuth or within Δφ )

The aircraft travels 30m in 300ms (=100ms-1 X 0.3s) (1 mark)

This will make the beam width of the “synthetic aperture”



Hence, angular resolution = 0.047 deg (1 mark)

Q4 (6 Marks)

(a) Beam widths when pointed at Zenith

The antenna dimensions are 3.5λX 4.5λ.

Hence the beam width in X-Z plane is (70/3.5) = 200

And beam width in Y-Z plane is (70/4.5) = 15.5560 (1X2=2)

(b) -10 degree tilt.

Phase to the element at (0,0) is taken as reference= 00.

Phase shift element at (1,0) = (dX Sin 100)/λ X360= 1X 0.173648/2 X360 = 31.25660

This phase will be lagging with respect to element at (0,0).

Phase shift element at (0,-2): This element is on Y axis and the beam tilt is in X-Z plane.

So will have same phase shift as (0,0)= 00. (1X2=2)

(c) -20 degree tilt

Phase shift element at (-1,0) = (dX Sin 200)/λ X360= 1X 0.342/2 X360 = 61.56360

This phase will be leading with respect to element at (0,0).

Phase shift element at (2,2): = (2dX Sin 200)/λ X360= 2X 0.342/2 X360 = 123.1270

This phase will be lagging with respect to element at (0,0). (1X2=2)

Q5 (6 Marks)

1. Matched filter is a ‘Linear Time Invariant (LTI)’ filter

Whose impulse response is the time reversed waveform of the transmit pulse.

OR Which correlates the received signal with replica of the transmit signal.

OR Mathematically, the impulse response is 

(Where, K is any arbitrary constant and N0 is the noise power)

OR the transfer function is



Any of the answers or equivalent is correct (give credit even if LTI is not mentioned) (0.5)

It maximizes the signal SNR

🡺 Thereby maximizing the ‘probability of detection’/ detectability (0.5).

(b)

Transmit-Pulse



2μs

+1 -1 +1 +1 +1

(1)

10μs

(c) Range resolution will be 300 (= cτ/2 = 3 X108 X 2X10-6/ 2=300m) (1)

(d) This radar cannot process the echoes arriving before completing the transmit pulse.

It takes 10μs. It corresponds to 1500 m or 1.5 km. (1)

(2 X range/c= 10 μs 🡺 Range= 10X10-6X3 X108/2=1500m)

(e) Received Echo

Correlation template slides:

1st Lag

=1

=0

🡺

2nd lag

=5

5th lag

- - 🡺

=1

9th lag

Position of the echo/ Main lobe

Auto-correlation Function

Range- side lobes

(f) Magnitude ratio 5: 1. (1)

Expressing it in dB, for magnitude, {use 20 log (ratio)}

20 log 5 = 13.979 dB ≈ 14 dB.