**EE 602 (2021-2): Quiz 2**

Date 13th April 2022 Maximum Marks: 10

**If any additional data/ conditions are required to reach the answer, please assume the same and mention clearly in the answer sheet. Write reason for your answer to the MCQs**

Q1 (6 marks**)**

Fig.2 Mono-static Radar with Circulator

Transmitter

Receiver

Array

Antenna

Duplexer OR

T/R Switch

Blanking Switch

Transmitter

Receiver with Single port Mixer

Fig.1 Mono-static Radar with Duplexer

Array Axis

Antenna

Beam

600

900

Broadside beam

ON/OFF ratio of transmitter= 90 dB Duplexer isolation =50dB

Blanking Isolation=50dB Circulator isolation= 30 dB

1. Pulsed radar operating at 1.5 GHz has a transmitter power 100 kW uses arrangement as shown in Fig.1. For this system to detect received signals 30 dB weaker than the transmitter leakage, the receiver must have following specifications

* Saturation power of receiver (Power input for receiver saturation): **> ‘X’ dBm**
* Receiver sensitivity: better than OR at power level < **‘Y’ dBm**. The values of X and Y are…

(a)-10, -100 (b) 10,-80 (c)-20, -90 (d)-20, -110 … (1 mark)

1. FMCW radar operating at 10 GHz has transmitter power of ‘Z’ Watt. The receiver performs ‘frequency-down-conversion’ of echo by mixing it with replica of the transmit signal (see Fig. 2). This down conversion is performed by a ‘single port mixer’ getting both the inputs (namely, ‘transmitter leakage as local oscillator (LO)’ and RF received signal (RF)) in the input port. For best performance (minimum conversion loss), this mixer requires Input power to be 7± 0.5 dBm. What should be the approximate value of ‘Z’.
2. 5 (b) 25 (c) 16 (d) It does not depend on Tx transmitter power … (1 mark)
3. For radars in Q1(i) and Q1(ii), a linear broad-side phased array antenna is used. ‘Broad side’ is the direction perpendicular to the array axis (defined =0°). This is also the main lobe or the intended direction of radiation (dark grey beam in Fig. 1 and Fig. 2). What must be maximum distance between adjacent radiating elements so that no grating lobes are observed in any other direction (±90°)?
4. 20 cm, 3 cm (b) 7.5 cm, 1.5 cm (c)20 sin(450)cm, 3sin(450)cm (d) 10cm, 2.1cm (1 mark)

(iv) A linear phased array has inter-element distance of ‘0.5 λ’. This array is required to steer the beam at an angle of 600 with respect to the array axis (or 30° w.r.t. broad side as shown by the light grey beam in Fig.2). What should be the phase difference between the adjacent elements?

(a) 1350  (b) (90√3)0 (c) 450 (d) 900 (1 mark)

(v) A pulsed radar uses ‘5 bit Barker code (+1 +1 +1 −1 +1)’. Receiver performs matched filtering by correlating the transmitted code. Due to this, an echo of a single target generates a peak at the target location and a few small peaks in adjacent ranges (known as range side-lobes). Assuming completely noiseless environment, what will be the number of false echoes (range side lobes) and their relative power compared to the power of the target echo? (1 mark)

(a) Four range-side-lobes of power 1/5 of the target signal

(b) Four range-side-lobes of power 1/25 of the target signal

(c) Two range side-lobes of 1/5 power and 2 range side-lobes of 1/25 power.

(d) Matched filter implementation does not lead to range side-lobes

(vi) A ‘Doppler radar’ tracks the targets using ‘sequential lobbing (SL) technique’ with four beams placed at 4 quadrature spots, making an angle of 1.20 with the antenna axis. Main receiving antenna beam width is 0.570(0.01 rad). The SL tracking update cycle requires total time of 50ms (4 beam spots requiring 5ms each and steering time of 10ms.) Two targets, A and B are spotted at 20 km. Target A and B have speeds of 1100 ms-1 and 850 ms-1 respectively. Which of the following statements is true? (Hint: The track is missed if the angular movement of the target is more than half beam width). (1 mark)

(a) Both A, B will be always be tracked by the radar

(b) B will always be tracked. A will be tracked depending on the direction of motion.

(c) Both A and B will be tracked if their motion is within certain angle the ‘look direction’.

(Look direction generally means antenna; line joining radar and target)

(d) The tracking mechanism is slow; in most of the cases, both the targets cannot be tracked.

Q2: Please provide scientific reasoning in brief (‘tell me why!’ 1-2 liners) (4 marks)

1. For the SL-tracking radar in ‘Q1-(vi)’, if the target distance is 10 km, which option will correctly describe the tracking ability? Will the situation change with target distance? How? (1 mark)
2. In a pulsed Doppler radar, a digital sampling receiver performs ‘coherent integration’ of the echoes coming from the same target. This is done by adding the echoes having identical round trip time from consecutive pulses. What is the main advantage? Quantify this advantage.

(1 mark)

1. Why microwave power amplifiers generate frequency harmonics’ (multiples of carrier frequencies)? Is there any disadvantage if operated like ‘low noise amplifiers (LNAs) without generating harmonics? (1 mark)
2. Why is there a limitation for high power generation using solid state devices? What is the technological issue? (1 mark)

**QUIZ-2 Answers (EE 602) date 13-4 -2022**

**Q1 (i) (c)**

100 kW= **80 dBm**, We compute the leakages during transmit and receive period

During transmission, **80-50-50=**-**20 dBm** (duplexer and blanking switch isolation) at the receiver,

So the receiver saturation level should be higher **0.5**

During receive period, the leakage shall be of **80-90-50= -60 dBm.** (ON-OFF ratio and Duplexer isolation). 30 dB signal is -90 dBm 0.5

(1 mark)

**(ii) (a)**

The transmitter leakage is used as LO which is equal to Z-30 dB=7 dBm. Therefore, Z=37 dBm.

1. Bm = 5 watt. (1 mark)

**(iii) (a)**

When the main lobe is at 90 degrees to the axis, in the limiting case, the grating lobe appear along the axis. The radiations from adjacent elements add in phase along the axis when the ‘**inter-element distance = λ’** (the max separation).For 1.5 GHz and 10 GHz, λ=20cm and 3 cm

(1 mark)

**(iv) (d)**

600 w.r.t. axis is same as 300 from the perpendicular to axis direction.

The required path difference is **= 0.5 λ sin (300)** = 0.25 **λ,** so phase difference is **900.** (1 mark)

1. **(b)**

N-bit Barker correlation sequence spans 2N+1 range bins. It shown matched of magnitude N and range side lobes of magnitude 1. Therefore, for 5 bit code, it will have 4 range side lobes at location 0 (matched) and at ±2 and ±4. Thus there will be 4 range side lobes of power 1.25 (square of magnitude

Total 5 peaks. 1(main)+ 4 (range side-lobes). Amplitude ratio = 5. 🡺 **Power ratio of 25**. (1 mark)

1. **(b)**

The radar has PRP of 100μs and transmit pulse time of 8 μs. Therefore the average power is 100X(8/100)= 8kW. And the resolution is corresponding to 2 μs, i.e. 300m.

**(vII) (a)**

The beam width is 0.01 rad. Total Processing time is 50 ms.

Target is missed if it moves by an angular distance of 0.005(half beam-width) rad within 50ms.

Maximum angular movement is seen if the target moves ‘transverse to the look direction’

At 15 km, angular movement of 0.005 rad, correspond to transverse distance of **0.005R=100m**.

The targets A and B move 55m and 42.5m in 50ms respectively. In whichever direction the targets move, they will not be missing the beam . . (1 mark)

**Q2**

1. (At a distance of 10 km, distance corresponding to 0.005 rad will be 50m.

Hence target A will conditionally be tracked (Option-b). (0.5 Marks)

At less than 8.5 km target B also will be conditionally tracked (option c). With further reduction of distance, the tracking of A and B will be possible in lesser transverse velocity range hence making it improbable, (option –d) (0.5 marks)

1. Coherent integration is performed to increase the signal to noise ratio (SNR). (0.5marks) Integration of ‘N’ pulses offer SNR (power) improvement by a factor of N. (1 mark)

Other possible versions

Signal amplitude becomes N times (power increase N^2 times). Noise being random process, N times addition increases the power by a factor of N. Hence SNR improvement ((N^2)/N) =N

Other possible answer (unusual)

For very low Doppler frequency targets, coherent integration reduces complexity of FFT computations. The length of the FFT points decrease by a factor of N.

1. Power amplifiers are operated in high efficiency modes (class C, D and above) to minimize power wastage. These are non-linear modes and introduce discontinuities in the waveforms. This generates harmonics (0.5 Marks). Like low noise amplifiers, If these amplifiers are operated in distortion-less / linear mode (A/AB), power efficiency will be very low (0.25 to 0.6). Such low efficiencies is impractical as it leads to wastage of substantial amount of power. (1 mark)

**(iv)** Frequency generation is caused by the carrier movements in active region of semiconductor devices. At microwave frequencies the gate/ base lengths (transition channels) of the devices can be at most a few micro-meters. This is due to the mobility values in semiconductor devices. At High power (≈100 W) a large number carriers of electrons are required which generate a large amount of heat which cannot handled by small volume of the semiconductors.

(Any equivalent points may be given credit) (1 mark)