EE 602: Practice problems- 4

**Short Questions**

1. A radar receiving system consists of super-heterodyne receiver (Rx) followed by a detector. The receiver (Rx) has noise figure (NF) of 3 dB has a sensitivity of -110 dBm (minimum input at which the signal is detected). Signal detection requires minimum signal to Noise ratio (SNR) of 5 dB at Rx output). What is the value of the noise power at the input of the receiver (in watts)? What is the bandwidth of the receiver? (Boltzmann constant= 1.38 ×10-23 J K-1) (1+1=2 Marks)
2. The transmitter power of radar is increased from ‘P’ dBW to ‘P+8’ dBW. What is the percentage increase in the maximum range? (1 Mark)
3. If a bi-static radar uses an isotropic antenna transmits power of 100 kW. What will be power incident on a target with radar cross section of 1 m2 at a distance of 30 km.
4. The range resolution of the radar depends on the band-width irrespective to the mode (pulsed or continuous); True or False? (1 mark)

(e) For radar operating at 10 GHz, what will be its range resolution if the transmit pulse contains exactly 5000 cycles of the carrier frequency? (1 mark)

**Problems**

1. FMCW radar based level measurement system is used to measure the liquid level in a large tank (reservoir). The radar is fitted to the ceiling of the tank and the antennas of the radar are pointed towards the liquid surface. The distance between the ceiling and the liquid is determined by finding the frequency difference between the transmitted and the received waveform (to get the beat frequency) and estimating the range. The transmitter frequency band is 9.3 to 9.5 GHz. This system is expected to measure the distance in the range of 1m to 10 meter.

Design a linear chirp (increasing frequency) FMCW radar level measurement system such that the beat frequency is in the range of LF frequency band (30 kHz to 300 kHz): Compute transmit frequency band, Frequency sweep time, Write the expression to relate the target distance and beat frequency. Draw a diagram showing the scheme. (2 marks)

1. Now, the distance measurement task is done by transmitting multiple chirp waveforms with varying the frequency sweep rates. Plan the scheme of multiple sweep rates (you may assume that the LF receiver works in the frequency band of 35 kHz to 65 kHz). Design the complete scheme of range estimation using multiple sweeps:

(ii) Compute sweep times for of all the sweeps. Alternatively, present mathematical approach with expressions. Draw the diagram explaining that. Compute the time for all the sweeps. (4 marks)

1. A wind Profiler (Mono-static pulse-Doppler radar for atmospheric observations) is operates at 600 MHz. Transmitter generates 20 kW. Pulse width is 1 μs. Effective area of array antenna is 7X7 m2. Antenna feed network has a loss of 1.25dB. Total insertion loss of duplexer and blanking switch is 0.5 dB. The volume reflectivity of target (air mass) is η=10-17 m2.m-3. (Clarification: The radar cross-section of a homogenous target is proportional to the volume occupied by the beam in a range-bin). Receiver sensitivity is -150 dBm.
2. What is the gain of the antenna? (1mark)
3. What will be the radar cross-section of the target range-bin at distance of 5 km.? (1mark )

EE 602: Answers to Practice problems- 4

1. The noise power at the input of the receiver must be -110-3-5= **-118 dBm** (1 mark)

= k X290 X B= -118 dBm = 1.5848 X10-15 W= 1.5848 fW.

Therefore Bandwidth **B =396.025 kHz**. (1 mark)

1. Increasing the power by 8 dB will increase in the range by 2 dB🡺 1.5849 times, 58% increase **OR** 8dB≈6.3. therefore, Range increase (6.3)0.25 = 1.58429 🡺 by ≈58% (1 mark)
2. Power density = Pt/(4πR2) = 100 X103/(4πX 30000X 30000) = **8.8419 μW.m-2** (1 mark)
3. True. For Pulse radar, Range Resolution is cτ/2= c/2ΔF.

Also for FMCW radars. (1 mark)

1. 5000 cycles of 10 GHz require (5X103/1010) =0.5 X 10-6= 0.5 micro second. Hence the resolution will be = (3 X108 X 0.5 X10-6 /2)= 75m (1 mark)

Q1.

(i)

ΔF= 9.5-9.3 GHz= 200 MHz

fb

2H/c

T

(1 amrk)



Sweep time should be such that 30 kHz should be obtained for 1m and 300 kHz for10 m.

Hence T should be **0.044444 ms. Or 44.444 microseconds.** (1 mark)

(ii) Multiple sweep system:

Time

Frequency

(1 mark)

The receiver bandwidth is50 kHz ±30%. One sweep shall cover range of R±0.3 R.

We should cover the range with the sweeps whose corresponding range band cover the entire range. We start with sweep time that correspond to ≈1.3m for 50 kHz.

T1= 0.03466 ms = 34.66 μs

This sweep will cover the range from ‘less than 1m’ to 1.7 m (1 mark)

Subsequent sweeps will be obtained by multiplying by a factor **1.6.**

The values of all the sweep times in μs are **34.66,** **55.457, 88.729,141.967and 227.147**

They are expected cover range bands with some overlap in meters,

(1-1.6), (1.6-2.7), (2.7-4.3),(4.3-6.8), (6.8-10). (2 mark)

Q2. (a)

Antenna gain = 4 π A/ λ2 = 2463≈ 33.91 dB

OR using expression for Gain = 4 π/ΔθΔϕ 🡺 Δθ=Δϕ =0.0714 rad = 4.09240

(Both answers may be given full credit)

(b) What will be the ‘radar cross-section’ of the ‘air-mass’ in the target at ? (1)

The value of cτ/2= 150m

The air: σ= η X mass volume =  (Cylindrical shaped approximation)

= 1 X 10-17 X 150 X π(0.0714)2 25 X 106 X 0.25 = 1.5014 X10-10m2

= 1 X 10-17 X 150 X π(0.0873)2 25 X 106 X 0.25 = 2.245 X10-10m2

OR =  (cuboids shaped approximation)

= 1 X 10-17 X 150 X (0.0714)2 25 X 106 = 1.912 X10-10m2

= 1 X 10-17 X 150 X (0.0873)2 25 X 106= 2.858 X 10-10m2

(Any of the answers may be given full credit)