Tutorial_1

Lindani Khuzwayo

```python
# import libraries
import numpy as np
import matplotlib.pyplot as plt
import math as m
# constants

c= 299792458
```

```python
def frequency_from_wavelength(wavelen):
    return c/wavelen

def wavelength_from_frequency(f):
    return c/f
```

```python
def antenna_beamwidth(wavelength,a):
    return 0.89*wavelength/a
```

```python
def time_range(distance):
    return 2*distance/c



def Range_one_way(total_time):
    return c*total_time/2
```

```python
def range_resolution(pulse_width):
    return c*pulse_width/2
```

```python
def doppler_shift(radial_velocity,wavelength):
    return 2*radial_velocity/wavelength
```

```python
def unambiguous_range_from_PRF(PRF):
    return (c)/(2*PRF)

def unambiguous_range_from_PRI(PRI):
    return c*PRI/2
```

```python
def duty_cycle(pulse_w,PRI):
    return pulse_w/PRI

def PRF(duty_cycle,pulse_width):
    return duty_cycle/pulse_width

def power_avg(peak_power,duty_cycle):
    return peak_power*duty_cycle

def linear_to_db(linear):
    return 10*np.log10(linear)

def db_to_linear(db_value):
    return 10**(db_value/10)
def unambiguous_doppler(PRF):
    return PRF/2
```

Chapter 1

1. A high-PRF radar has a pulse width of 1.0 μs and a duty factor of 20%. What is this radar's maximum unambiguous range?

```python
x=PRF(0.2,1.0*10**-6)
print(x)
print(unambiguous_range_from_PRF(x))
```

```
200000.00000000003
749.4811449999999
```

1. What is the maximum unambiguous Doppler shift that can be measured with a radar with a PRI of 0.25 milliseconds?

```python
print(unambiguous_doppler(0.025*10**-3))
```

```
1.25e-05
```

1. Consider a 2-D search radar having an antenna that is 6.5 meters wide. If it is rotating (in azimuth) at a constant rate of 0.8 radians per second, how long is a potential target in the 3 dB beam if the operating frequency is 2.8 GHz?

Chapter 2

1. Using equation (2.10), determine the receiver noise power (in dBm) for a receiver having a noise figure of 2.7 dB and an instantaneous bandwidth of 1 MHz.

```python
def receiver_thermal_noise(F,B):
    return 1.38*10**-23*290*F*B

k=1.38*10**-23
T=290
```

```python
P=linear_to_db(receiver_thermal_noise(db_to_linear(2.7),1*10**6))
print(P)
```

```
-141.2772291569981
```

1. A radar system provides 18 dB SNR for a target having an RCS of 1 square meter at a range of 50 km. Ignoring the effects of atmospheric propagation loss, using equation (2.18), determine the range at which the SNR will be 18 dB if the target RCS is reduced to:

```python
from IPython.display import Image
image_path = "p9.jpeg"

Image(filename=image_path)
```

Out[1]:

Problem 9 - Chapter 2

Given: $SNR_1 = 18\,dB$, $RCS_1 = 1\,m^2$, $R_1 = 50\,km$

$SNR_2 = 18\,dB$, $RCS_2 = 0{,}5\,m^2$, $R_2 = x_2$

$SNR_3 = 18\,dB$, $RCS_3 = 0{,}1\,m^2$, $R_3 = x_3$

$\therefore SNR_1 = SNR_2$

$$\frac{P_t G_t G_r \lambda^2 \sigma_1}{(4\pi)^3 \cdot R_1^4 k T_0 F B} = \frac{P_t G_t G_r \lambda^2 \sigma_2}{(4\pi)^3 R_2^4 k T_0 F B}$$

Solving for R_2 in the above expression:

$$R_2 = R_1 \times \left(\sigma_2/\sigma_1\right)^{1/4}$$

$$\therefore R_{new} = R_{old}\left(\frac{\sigma_{new}}{\sigma_{old}}\right)^{1/4}$$

a) $R_{new} = 50\times10^3 \times \left(0{,}5/1\right)^{1/4} = \underline{42{,}045\,Km}$

b) $R_{new} = 50\times10^3 \times \left(0{,}1/1\right)^{1/4} = \underline{28{,}117\,km}$

1. How much power is received by a radar receiver located 100 km from a jammer with the following characteristics? Assume that the radar antenna has an effective area of 1.2 square meters and that the main beam is pointed in the direction of the jammer. Consider only atmospheric attenuation, excluding the effects of, for example, component loss. Provide the answer in terms of watts and dBm (dB relative to a milliwatt.)

```python
def power_received_jammer(P,G,A,R,L):
    return (P*G*A)/(4*np.pi*R**2*L)
# Given parameters
P_t = 100  # Jammer peak power in watts
G_t_dB = 15  # Jammer antenna gain in dB
A_e = 1.2  # Effective area of the radar antenna in square meters
R = 100000  # Distance between the jammer and the radar in meters
L_per_km = 0.04  # Atmospheric loss in dB per km


# Calculate total atmospheric loss
total_loss = L_per_km * (R / 1000)  # Convert distance to km and multiply by loss per km

# Convert atmospheric loss from dB to linear scale
L = 10**(total_loss / 10)



# Convert jammer antenna gain from dB to linear scale
G_t = 10**(G_t_dB / 10)

# Convert the received power to dBm (dB relative to a milliwatt)

P_received=power_received_jammer(P_t, G_t, A_e, R, L)
P_received_dBm = 10 * np.log10(P_received / 0.001)
P_received_dB=linear_to_db(P_received)


print('Results power_recieved by jammer antenna')
print(power_received_jammer(P_t, G_t, A_e, R, L), "watts")
print(linear_to_db(power_received_jammer(100,db_to_linear(15),1.2,100*10**3,L)), "dB")
print(P_received_dBm, "dBm")
print(P_received_dB)
```

```
Results power_recieved by jammer antenna
1.2021852136262495e-08 watts
-79.20028617974471 dB
-49.20028617974471 dBm
-79.20028617974471
```

1. Using the answers from problems 2 and 14 what is the jammer-to-noise ratio (JNR)?

```python
print(P/P_received_dB , "dB")

print((10 * np.log10(db_to_linear(P)/ 0.001))/(P_received_dBm), 'dBm')
```

```
1.783796952909615 dB
2.261719144284365 dBm
```

1. A search system being designed by an engineering staff has to search the following solid angle volume in the stated amount of time: • Azimuth angle: 90 degrees • Elevation angle: 3 degrees • Full scan time: 1.2 seconds • Maximum range: 30 km Target RCS: −10 dBsm What is the required power aperture product of the system if the system has the following characteristics? • Noise figure: 2.5 dB • System losses: 6.7 dB • Required SNR: 16 dB

```python
from IPython.display import Image
image_path = "p1.jpeg"


Image(filename=image_path)
```

Out[5]:

(15) $$\frac{P_{avg} \cdot A_e}{L_s \cdot T_0 F} \geq SNR_{min}\, 4\pi k \times \left(\frac{R^4}{\sigma}\right)\left(\frac{\Omega}{T_{fs}}\right)$$

$L_s = 2{,}5 + 6.7 = \underline{9.2\,dB} \approx$ $\qquad K = 1{,}38\times10^{-23}$

$L_s = 8{,}3176 \approx \underline{10^{(9{,}2/10)}}$

$\underline{T_0 = 290\,K}$ $\qquad \Omega =$ $\qquad T_{fs} = 1{,}2$

$F = 2.5\,dB \approx \underline{10^{(2{,}5/10)}}$ $\qquad R = 30\times10^3$

$SNR_{min} = \underline{10^{16/10}}$ $\qquad RCS = 10^{-10/10}$

```python
from IPython.display import Image
image_path = "p2.jpeg"
Image(filename=image_path)
```

Out[6]:

$$\frac{P_{avg} \cdot A_e}{10^{(9{,}2/10)} \times 290 \times 10^{2{,}5/10}} \geq 10^{16/10} \times 4\pi \cdot 1{,}38\times10^{-23}\left(\frac{30\times10^3}{10^{-10/10}}\right)\left(\frac{90\times3}{1{,}2}\right)$$

$$P_{avg} \cdot A_e \geq \frac{4.66\times10^{-14}}{\left[10^{9.2/10} \times 290 \times 10^{2{,}5/10}\right]^{-1}} = \underline{1{,}999\times10^{-10}}$$

Chapter 3

1. Your enemy, 20 km distant, fires a mortar round in your general direction. The round has a vertical component of velocity of 200 meters per second. (Assume that this does not change during the search time.) You are searching the area using a weaponlocating radar. What must your maximum scan time be to ensure at least four opportunities to detect the target before it passes through your "search fence," which is the elevation sector extending from 0 to 4 degrees above the horizon?

1. Given a radar system that has a single-dwell PD of 50% and a single-dwell PFA of 5 × 10−3, what are the cumulative PD and PFA for 2-of-3 and 2-of-4 multiple-dwell processes?

```python
# Given single-dwell PD and PFA
single_dwell_PD = 0.90
single_dwell_PFA = 0.01


num_dwell = 5
num_detection_required = 3


PD_3_of_5 = 1 - (1 - single_dwell_PD)**num_detection_required


PFA_3_of_5 = single_dwell_PFA * num_dwell

PD_3_of_5, PFA_3_of_5
```

```
(0.999, 0.05)
```

1. Suppose a phased array search radar has to complete searching a volume defined by 10 degrees in azimuth, 10 degrees in elevation, and 40 km in range in 0.62 seconds. The range resolution is 150 meters, obtained with a simple 1 microsecond pulse width. At the center of the search sector, the antenna has a 2.7 degree azimuth beamwidth and a 2.7 degree elevation beamwidth. Since the target for which the system is searching is a moving target and there is surface clutter interfering with the detection, Doppler processing is used. There are 64 Doppler bins developed by the FFT processor. During a single search pattern, it is required that the probability of detecting a target is 99%, and on average one false alarm is allowed. What is the resulting PD and PFA if the single-dwell PD is 90% and the single-dwell PFA is 0.01? If 3-of-5 processing is employed, do the resulting PD and PFA meet the requirements?

```python
import numpy as np

# Given azimuth and elevation coverage in degrees
azimuth_coverage_deg = 10
elevation_coverage_deg = 10

# Converting azimuth and elevation coverage to radians
azimuth_coverage_rad = azimuth_coverage_deg * np.pi / 180
elevation_coverage_rad = elevation_coverage_deg * np.pi / 180

# Given range coverage in meters
range_coverage_m = 40 * 1000  # Convert from km to meters

# Calculating the volume of the search sector
volume_search_sector = azimuth_coverage_rad * elevation_coverage_rad * range_coverage_m
volume_search_sector
```

```
1218.4696791468343
```