

Final Report

Radar Engineering

Drone Detection Radar

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1. Title

Drone detection radar

2. Purpose

Recently, the use of drones is rapidly increasing due to the development of wireless communication technology and aviation technology. Drones are used in various places such as agriculture and military. However, as the amount of drone business increases, problems such as invasion of privacy and noise pollution caused by unauthorized flight in the no-fly zone are occurring, and terrorism using drones is also increasing rapidly. According to the British online media The Independent, crimes using drones are increasing every year, and although safety threats were the most common, cases of various types of crimes and antisocial activities such as theft and sex crimes are increasing. In November 2021, the Iraqi prime minister was attacked by a drone carrying explosives at the prime minister's residence. Although drone crimes such as terrorism are still occurring in Korea, technology to respond to illegal drones is needed in light of global trends. Therefore, the project will design a drone detection radar that can detect illegal drones.

3. Group Implements

3-1. Maximum detection range of radar

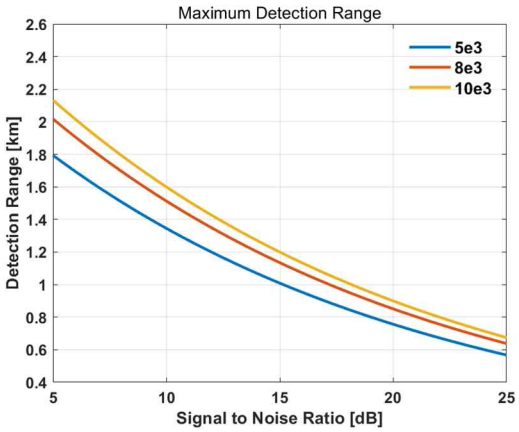
Expression of Radar's maximum detection range R_{max} is showed below.

$$\mathbf{R_{max}} = \left(\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 k T_0 B F (SNR_{min})}\right)^{1/4} = \left(\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 k T_0 B F (S_{min})}\right)^{1/4}$$

In order for a target to be detected, the SNR assumes that there is a certain minimum value and no maximum value. In the expression of the maximum

detection range, the SNR exists in the denominator, and the slope of the graph of the maximum detection range versus the SNR will show an inversely proportional shape.

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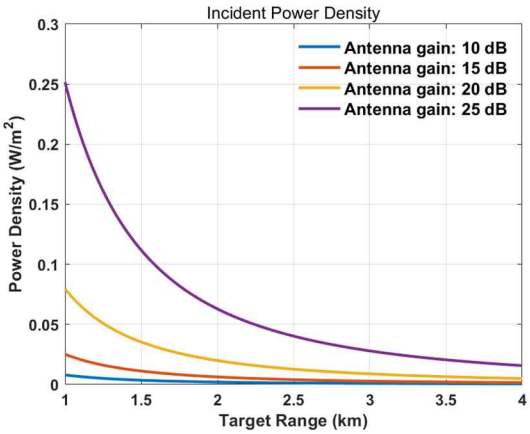
Input parameter	
P_t	Peak transmitter power
G_t	Antenna gain
λ	wavelength
σ	Target RCS
S_{min}	Minimum detection signal

3-2. Power density according to target distance

$$Power\ density\ from\ directive\ antenna = \frac{P_t G_t}{4\pi R^2}$$

G: transmit antenna gain
G = (Antenna's maximum radiation intensity)/(Radiation intensity of non-attenuation, omni-directional antenna)

Assume that the enemy drone is within 2 km and observe how the trend of the power reaching the target within 2 km changes when the radar emits. The following figure shows the relationship between power density and distance according to antenna gain.



Input parameter		
P_t	Peak transmitter power	10×10^3 W
G_t	Antenna gain	30 dB
λ	wavelength	1 ~5 km

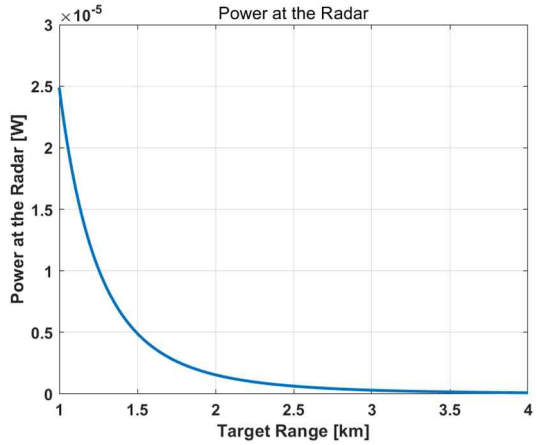
3-3. Received power density according to target distance

$$P_r = \frac{P_t G_t}{4\pi R^2} \times \frac{\sigma}{4\pi R^2} \times A_e = \frac{P_t G_t A_e \sigma}{(4\pi)^2 R^4} = \frac{P_t G_t \lambda^2 \sigma}{(4\pi)^3 R^4}$$

A_e: Efficient area of receive antenna

In relation to calculation of maximum detection range of radar, the total round-trip distance from the radar to the target is 4 km. At this time, a trend of change in received power density versus distance is examined.

At a frequency of 2.4 GHz, the radar can detect the target if the received power density is greater than -30 dBm (1 um).\



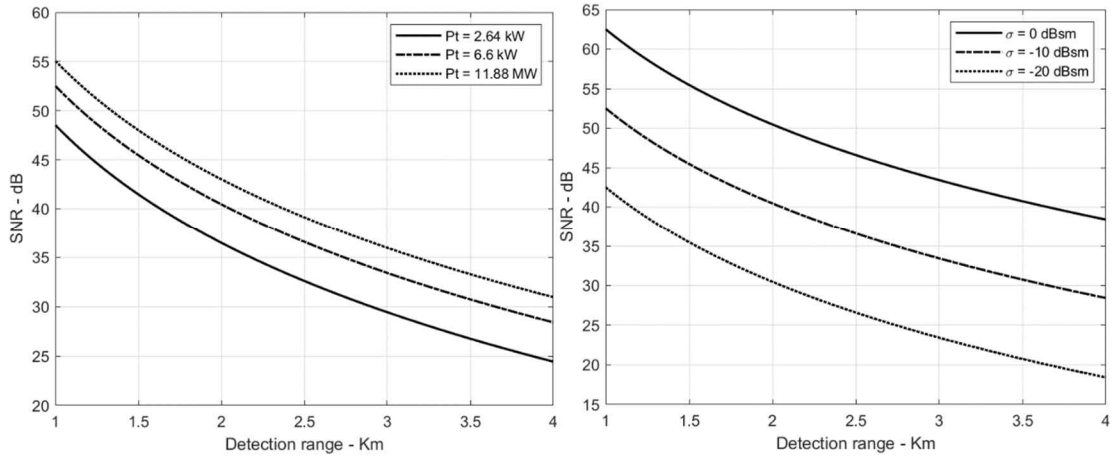
Input parameter		
P_t	Peak transmitter power	10×10^3 W
G_t	Antenna gain	30 dB
λ	wavelength	$c/(10^9$ Hz)
σ	Target RCS	35 dBsm
S_{min}	Minimum detection signal	1 ~ 4 km

3-4. SNR range of radar

In order for the target to be detected, the SNR must be above the criterion and the maximum detection distance is determined within a range where the SNR of the signal satisfies the required value of the system.

Measure the SNR range of the radar using the radar specifications such as peak power, antenna gain, and radar operating frequency set above. At this time, the SNR is calculated by adjusting the target detection distance, RCS, and power.

Input parameter		
P_t	Peak transmitter power	10×10^3 W
G_t	Antenna gain	30 dB
λ	wavelength	$c/(10^9$ Hz)
σ	Target RCS	35 dBsm



4. Constant False Alarm Rate (CFAR)

Constant false alarm rate (CFAR) detection refers to a common form of adaptive algorithm used in radar systems to detect target returns against a background of noise, clutter and interference.

Receiver monitors background and adjusts the SNR to maintain a constant false alarm rate. CFAR could be highly desirable and is a performance prerequisite in a changeable environment. The cells for estimating the background may contain thermal anomalies and this cause overestimation of the adaptive threshold.

4-1. Cell Averaging Algorithm

① Sensing average interference level

② Set the threshold so that a relatively constant number of false alarm occurs per unit of time

③ Averages all signal data in estimation window

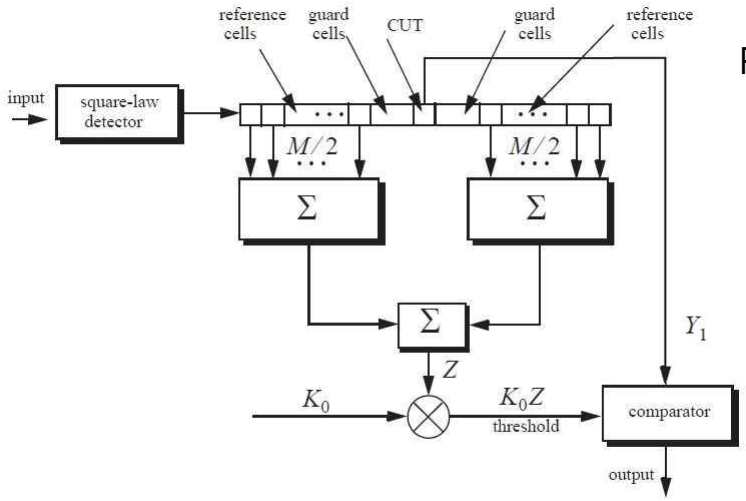


Figure 13.15. Conventional CA-CFAR.

Parameter Settings

- Guard cell : 2
- Reference cell : 10
- Window cell : Reference cell + Guard cells = 12
- Number of sample : 1000
- Frequency : 2.4 GHz

4-2. Constant False Alarm Rate (CFAR) Results

In the figure below, the red line represents the threshold value. The target can be detected as shown in the figure above by using the overlapping part of the threshold value and the blue line.

