

CUMCM-2026 Problem B

Fast Automatic Localization and Elimination of Radio Jammers

Localization and elimination of radio jammers are important tasks in radio spectrum management. The localization of radio jammers involves three stages: Preliminary monitoring, regional inspection, and precise localization. The first two stages use fixed monitoring stations, mobile monitoring vehicles, or UAVs to collect and analyze signals over a wide region and determine the distribution area of the jammers. However, due to factors such as environmental obstructions and low-power jammers, the precise localization of each jammer ultimately requires technicians to operate within the target distribution area. To quickly eliminate the adverse impact of the jamming, the completion time of this task should be as short as possible. In the precise localization stage, technicians carry portable radio direction-finding equipment (referred to as Radio-DFE) and investigate on foot. By observing changes in signal field strength and direction, combined with experience, they gradually locate and eliminate each jammer. The characteristics of jammers are given in Appendix 1.

A company intends to develop an autonomous jammer localization and removal system mounted on a robot dog, capable of substituting for technicians in performing localization and elimination in hazardous environments, so as to enhance overall efficiency. The detection principle and operational methodology are provided in Appendix 2.

The target distribution area of the jammers has been identified as a circular region with a radius of 1800 m. The origin of the coordinate system is set at the center of this circular area, with the eastward direction as the positive x -axis and the northward direction as the positive y -axis (units: m). The number of jammers in the target area is unknown.

Please establish mathematical models to solve the following problems.

Problem 1 Given the coordinates of multiple detection points and the indicated bearings of a jammer at these points, please provide an algorithm for computing the diameter of the polygonal localization region (i.e., the maximum distance between any two points within the region) using the intersection localization method (see Appendix 2). Can a circle with the diameter of the localization region cover the entire region?

Problem 2 Given the indicated bearing of an omnidirectional jammer measured at a single detection point, please provide a strategy for selecting the second detection point to obtain better localization results for the jammer, and specify the candidate region for this second detection point.

Problem 3 All jammers in the target area are known to be omnidirectional, with a total number ranging from 10 to 16, but the exact number is unknown. A robot dog, starting from the origin with the Radio-DFE initially set to Channel 1, is deployed to automatically locate and eliminate the jammers in the target area. The goal is to complete the task in the shortest possible time while ensuring that all jammers are eliminated. Please formulate a strategy for the robot dog's automatic search, localization, and elimination, and design the corresponding algorithm. Please use the simulator to perform drill tests (see Appendix 3), and compute the following statistics related to the drill test to verify the effectiveness of the strategy:

$$\text{Ratio of eliminated jammers} = \frac{\text{Number of eliminated jammers}}{\text{Total number of jammers}}$$

$$\text{Average localization and elimination time} = \frac{\text{Total localization and elimination time}}{\text{Number of eliminated jammers}}$$

where the total localization and elimination time includes the robot dog's movement time, channel switching time, detection time, optical precision positioning time, elimination time, etc.

After sufficient drill testing, perform three formal tests (see Appendix 3). Please provide the results of each formal test in the format of Table 1 in the paper. Export the log files of the three formal tests from the simulator (do not modify the file names) and put them in the supporting materials.

Table 1 Formal test results for Problem 3

Test case code	Number of eliminated jammers	Average localization and elimination time	Program execution time
Test 1 case code			
Test 2 case code			
Test 3 case code			

Problem 4 The target area is now known to contain both omnidirectional and directional jammers, with a total number ranging from 10 to 16, but the exact number, as well as the number and direction of the directional jammers, is unknown. All other conditions are the same as in Problem 3. Under these conditions, please provide a strategy and algorithm for detection and elimination, and perform drill tests by using the simulator (see Appendix 4) to verify the effectiveness of the strategy.

After sufficient drill testing, perform three formal tests (see Appendix 4). Please provide the results of each formal test in the format of Table 1 in the paper. Export the log files of the three formal tests from the simulator and put them in the supporting materials.

Appendix 1 Characteristics of Jammers

(1) The channels of each jammer are mutually distinct, which does not vary over time. The channels used by the jammers are among 20 common frequency channels, numbered from 1 to 20 according to the different center frequencies of each channel.

(2) The signals from different jammers do not interfere with each other.

(3) Based on the angular coverage of signals, jammers are classified into two types: omnidirectional and directional. Omnidirectional jammers have no specific transmission direction, with an effective coverage angle of 360° . On the other hand, directional jammers have a specific transmission direction (referred to as orientation), with an effective coverage angle of 90° on both sides of the orientation (inclusive). There is no signal radiation outside this angular range.

(4) Within the effective coverage angles, both omnidirectional and directional jammers radiate signals uniformly. The field strength decays only with distance and is independent of angle.

Appendix 2 Principle and operating methods of the Radio-DFE and other equipment

(1) The Radio-DFE determines the azimuth of a jammer relative to the detection point by detecting field strength variations. With the detection point fixed, the detected field strength is at its maximum when the receiving antenna is pointed at the jammer. The azimuth angle of the direction in which the maximum field strength direction of the jammer is received at the detection point by the Radio-DFE is referred to as the indicated bearing measured by the Radio-DFE at that point. Here the azimuth angle is defined as the angle rotating counterclockwise from the positive x-axis to the vector pointing from the detection point to the jammer (unit: degree, range $[0^\circ, 360^\circ)$). Due to environmental influences and limitations in direction-finding accuracy, the readings of the Radio-DFE are subject to the local electromagnetic environment, causing deviations between the indicated bearing and the true azimuth angle of the maximum field strength direction of the jammer. Over a period of time, the electromagnetic interference at the same location remains constant, hence repeated measurements do not change the detection error. Only in different locations and different electromagnetic environments do the errors exhibit statistical regularity. Across the entire target area, all errors are within $[-1^\circ, 1^\circ]$ (see Figure 1).

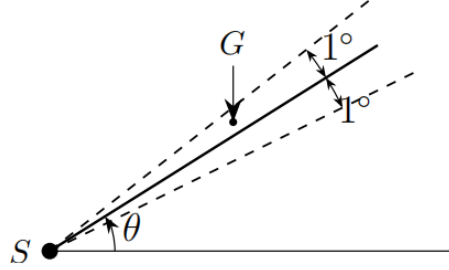


Figure 1 Schematic diagram of the indicated bearing of jammer G with respect to detection point S

(2) The sensitivity of the Radio-DFE refers to the minimum field strength of the signal that can be effectively received. In this problem, both the transmission power of each jammer and the sensitivity of the Radio-DFE are predetermined. The maximum effective reception distance (hereinafter referred to as the effective reception radius) for each jammer is between 1000 and 1500 m.

(3) For the localization of multiple jammers, the intersection localization method is commonly used. Figure 2 is a schematic diagram of the intersection localization of the same jammer G using two detection points S_1 and S_2 . In the figure, the directions of the two solid lines indicate the bearing directions of G measured at S_1 and S_2 , respectively. The angle between each solid line and the adjacent dashed line is 1° . The red quadrilateral is referred to as

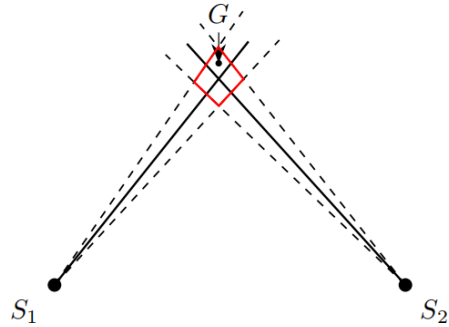


Figure 2 Schematic diagram of the intersection localization method

the localization region.

(4) The Radio-DFE cannot simultaneously detect the field strength of multiple channels. Whenever the detection channel needs to be changed, the current channel needs to be switched to the desired channel before performing detection. The switching time between any two channels is 1 s.

(5) Effective detection cannot be performed during movement; it must stop to perform detection. Therefore, when the robot dog performs detection at any point, it first stops moving, switches to the desired channel, and then continuously adjusts the antenna direction to obtain the indicated bearing of the jammer in that channel. The time to adjust the antenna direction and obtain a stable bearing reading (or confirm that no signal is detected) is 5 s.

(6) The robot dog moves in a straight line at a speed of 5 m/s.

(7) Ignoring the height difference between the Radio-DFE carried by the robot dog and the jammers, i.e., the Radio-DFE and all jammers are located on the same plane.

(8) Due to environmental interference factors and limitations of instrument parameters, the simple optical detector carried by the robot dog can precisely locate a jammer only when the distance to the jammer is no more than 20 m, after which it can activate the laser gun to eliminate it. The time for optical precision positioning is 3 s, and the time for elimination using the laser gun is 2 s. Whether the optical precision positioning and elimination are successful only depends on the distance between the elimination point and the jammer, and is independent of the effective coverage angle of the jammer signal.

(9) When the distance between the detection point and the jammer is no more than 5 m and the detection point is located within the effective coverage angle of the jammer signal, due to the strong signal, indicated bearings cannot be obtained. In this case, optical precision positioning can be directly performed and the jammer eliminated.

Appendix 3 Test instructions for Problem 3

Please first download the Radio Jamming Environment Simulator (hereinafter referred to as the simulator) for testing. The simulator can simulate the electromagnetic environment of the target area. The robot dog communicates with the simulator via the HTTP+JSON interface, sends detection, elimination, and other commands, and receives the detection results or elimination results from the simulator. It detects and eliminates jammers according to the algorithm you designed. The communication protocol, the specific test procedures, and requirements are detailed in Attachments 1 and 2.

Each case in the testing includes the following data: The number of jammers in the target area, channel numbers, positions, effective reception radii, etc. All data cannot be read directly. The test is divided into two modules: “drill test” and “formal test”. The drill test is used to test the effectiveness of the strategies and algorithms. The testing environment and operations are exactly the same as those of the formal test, but there is no limit on the number of tests, and the number of jammers will be provided at the end of the test.

You will perform three formal tests, with the simulator randomly generating a case each time. After you confirm the start of the test, the simulator first prepares the case data. Once all preparations are ready, the simulator displays a 5-second countdown. When the countdown ends, a 25-minute testing window opens and the robot dog interface becomes available. The “Abort Test” button is only for manually terminating the test; but this test cannot be canceled, and it still counts

as one test attempt.

The robot dog should call “/enter” to enter the target area only after the interface is shown as ready. After a successful “/enter” call, the virtual time of the robot dog and the program execution time begin to count. The program execution time has a maximum of 20 min, and the test is also subject to a 25-minute window limit, with the earlier of the two deadlines taking precedence. Therefore, if “/enter” is successfully called within 5 min after the 25-minute window opens, the full 20 min can be utilized; if the entry occurs later than 5 min, the actual available time will be less than 20 min. The response to “/enter” will return the actual remaining program execution time for this test.

The initial position of the robot dog for each test is (0,0), and the initial channel is 1. The duration of the robot dog's activities in the virtual world is usually not a constraint. However, to prevent program deadlock, an upper limit of 100 hours is set. The position of the robot dog is not constrained either. However, to avoid numerical anomalies, the absolute value of each coordinate component submitted to the interface must not exceed 2,000,000 m.

After completing the task, the robot dog should call “/exit” to actively end the test. The test will be terminated under any of the following conditions: active exit, manual abort, timeout of 25-minute window, timeout of the program execution after “/enter”, timeout of virtual time, or technical exception. Generally, the duration between the “/enter” command and the end of the test is regarded as the program execution time for that test. After each formal test, the simulator generates an encrypted behavior log and automatically adds it to the upload queue. You also need to export the corresponding log from the simulator and include it in the supporting materials.

Both drill tests and formal tests require the simulator to maintain network connectivity throughout the entire process, and require online login and server time verification to be completed before starting the test.

After 17:30 Beijing time on September 13, 2026, the simulator will not be able to start new drill tests or formal tests. Tests that have already started before that time are not affected and can be completed normally. As long as a behavior log has already entered the upload queue, the simulator will continue to upload it automatically until completion, regardless of the time limit. To avoid network congestion in the late stage of the contest, it is recommended to perform the formal tests as early as possible, and it is suggested to complete all formal tests before 15:30 Beijing time on September 13, 2026.

Appendix 4 Test instructions for Problem 4

Each case in the test includes the following data: The number of jammers in the target area, channel numbers, positions, effective reception radii, directional bearings, etc., where the directional bearing of an omnidirectional jammer is null. None of this data cannot be read directly. The test is also divided into two modules: “drill test” and “formal test”. The testing environment and operations of the drill test are exactly the same as those of the formal test, but there is no limit on the number of tests, and the number of jammers will be provided at the end of the test.

In the formal test, the initial state of the robot dog, startup procedure, time limits, networking requirements, behavior logs, deadlines, etc., are the same as those for the formal test of Problem 3. You will perform three formal tests, with the simulator randomly generating a case each time.