

CUMCM-2026 Problem D

Detection and Elimination of Time-Frequency Conflicts among Frequency-Using Equipment

With the rapid increase in the number of frequency-using equipment, electromagnetic compatibility conflicts have become increasingly prominent. When formulating a frequency usage plan, it is necessary to detect and eliminate potential time-frequency conflicts to avoid mutual interference and constraints among frequency-using equipment.

Now consider a scenario in a specific area where a large number of frequency-using equipment have demands for frequency resources with a limited bandwidth over a period of time. To simplify the problem, the time-frequency resources are discretized as follows: In the time domain, a fixed time length Δt is used as the basic unit of time resources, representing the minimum indivisible duration for which the equipment uses the frequency. It is restricted that the duration occupied for a frequency usage plan must be an integer multiple of Δt . In the frequency domain, the limited bandwidth frequency resources available in the system are discretized into 100 frequency segments with the same width using a fixed frequency bandwidth Δf . Each frequency usage plan can occupy multiple consecutive frequency segments, and the number of occupied segments remains unchanged.

All frequency-using equipment has been submitted their frequency usage plans, and it is necessary to detect potential time-frequency conflicts from these submitted plans. The frequency usage plan of each piece of equipment contains four parameters: The frequency segment range, the time interval of the first use, the spacing between two consecutive uses of the same frequency segment, and the number of uses. When both the time intervals and frequency segment ranges of two frequency usage plans overlap, a time-frequency conflict is determined to exist between them. The elimination of time-frequency conflict involves adjusting the parameter of certain frequency usage plans (such as shifting the frequency segment range or time interval, etc.), or even canceling certain frequency usage plans, so that no time-frequency conflicts exist.

A frequency usage plan can only have one parameter adjusted or be canceled. For detected time-frequency conflicts, the number of uses and the usage spacing are generally not adjusted unless otherwise specified. The number of canceled frequency usage plans should be minimized as much as possible, so should be the number of adjusted frequency usage plans. Among the frequency usage plans, Class A frequency-using equipment has the highest priority, followed by Class B, and Class C has the lowest priority. High-priority frequency usage plans should be retained as much as possible. The adjustment range should be minimized, with the maximum adjustment range for frequency segments and time specified as $10\Delta f$ and $5\Delta t$, respectively.

Attachment 1 provides the frequency usage plans submitted by 150 frequency-using equipment of three classes. Please establish mathematical models to solve the following problems.

Problem 1 Perform time-frequency conflict detection on the frequency usage plans provided in Attachment 1. Save the results to the file result1.xlsx (the template file is provided in Attachment 2), and present the statistical results of time-frequency conflicts in the paper.

Problem 2 Eliminate the time-frequency conflicts detected in Problem 1. Save the elimination plan to the file result2.xlsx (the template file is provided in Attachment 2), and present

the statistical results of the elimination of time-frequency conflict in the paper in the format of Table 1.

Table 1 Statistical results of the elimination of time-frequency conflict

Class	Number of retained equipment	Number of adjusted equipment	Number of canceled equipment
A			
B			
C			

Problem 3 Based on the conflict-free frequency usage plan in Problem 2, and without increasing time-frequency resources. If there are no limits on the shift range of frequency and time, how much the maximum number of additional Class C frequency-using equipment can be arranged? Provide the corresponding frequency usage plans and save the results to the file result3.xlsx (the template file is provided in Attachment 2).

Problem 4 If some Class C frequency-using equipment is allowed to adjust their spacing, but the difference from the original spacing must not exceed $10\Delta t$, please re-eliminate the time-frequency conflicts detected in Problem 1. Save the elimination plan to the file result4.xlsx (the template file is provided in Attachment 2), and present the statistical results of the elimination of time-frequency conflict in the paper in the format of Table 1.

Appendix Description of attachments

Attachment 1 Frequency usage plan of frequency-using equipment

Taking frequency-using equipment A001 as an example. The frequency interval $[80,90)$ indicates that the occupied frequency interval is $[f_0 + 80\Delta f, f_0 + 90\Delta f)$, where f_0 is the lower limit of this limited bandwidth frequency resource. The time interval $[35,40)$ indicates that the first time in the time interval $[35\Delta t, 40\Delta t)$. The spacing 60 indicates that the frequency segment is occupied with the same length of time again after $60\Delta t$, i.e., the second occupied frequency interval of the frequency segment $[f_0 + 80\Delta f, f_0 + 90\Delta f)$ is $[40\Delta t + 60\Delta t, 45\Delta t + 60\Delta t)$. The number of uses 3 indicates that this frequency interval is used 3 times according to the above rules.

Attachment 2 A folder containing the template files for the result files

result1.xlsx template files for the results of problem 1

Fill all conflicting equipment pairs in the sheet, with the index number in column A and the numbers of two conflicting equipment in columns B and C, respectively.

result2.xlsx template files for the results of problem 2

Fill each adjusted equipment in the sheet. If the frequency interval needs to be adjusted, fill the equipment number in column A and the adjusted frequency interval in column B. If the time interval needs to be adjusted, fill the equipment number in column A and the adjusted time interval in column C. If the frequency usage plan is canceled, fill the equipment number in column A and "Yes" in column D.

result3.xlsx template files for the results of problem 3

Fill each new Class C frequency-using equipment in the sheet. Fill the index number in column A and the corresponding frequency interval and time interval in columns B and C, respectively.

result4.xlsx template files for the results of problem 4

Fill each frequency-using equipment that requires adjustment into the sheet. Fill the equipment number that requires adjustment in column A. If the frequency interval needs to be adjusted, fill the adjusted frequency interval in column B. If the time interval needs to be adjusted, fill the adjusted time interval in column C. If the spacing needs to be adjusted, fill the adjusted spacing in column D. If the frequency-using equipment is canceled, fill 'Yes' in column E.