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Surrounding Boards Effects on Component Temperatures of Target Board in Telecom Rack with Active or Passive Cooling

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Abstract: The understanding of the effect of the empty slots in the card cage on the thermal analysis and the tests is extremely important. The detailed full scale thermal model of the rack is often too large to be for the practical applications. Similarly, the fillers which are often referred to as the dummy boards are frequently required during the system thermal tests to insure the proper flow distribution to all slots (or boards). The purpose of this study is to examine the effect of filler on the component temperatures of the target board under active (forced convection) and passive (natural convection) cooling. The results indicated that no noticeable difference in the component temperatures between the cases of the fully loaded and partially filled card cages under the forced air cooling with the fans. However, the cases with the partially filled card cage significantly reduce the component temperatures of the heated boards as compared with the fully loaded card cage for natural convection cooling. Therefore, the thermal simulations and/or tests for the passive cooling should be conducted under the actual operation conditions with the full power on all boards in the card cage.

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1. Introduction

Generally, the entire thermal design process for telecommunication equipment can be divided into 3 phases which are summarized in the following steps:

1) Phase 1: System level thermal design which does not include any details of individual boards

to determine the flow rate to individual boards

2) Phase 2: Board level thermal design based on the flow rate obtained from the system level analysis to compute the component junction temperature of individual boards

3) Phase 3: Final thermal analysis of the entire system, including the details of individual boards

Theoretically, the final thermal model should include all detailed boards in the system. Unfortunately, the thermal model in such case will be too large to run and it becomes unpractical. Therefore, there are many approximate methods, including using dummy boards (fillers) which have proper pressure drop of the boards.

The thermal /CFD analysis is probably an easy part of the entire thermal design process. The thermal design process must also include the testing at various stages of the design cycle, especially at the final full scale thermal tests to verify the results from the analyses. Because of extremely long lead time for production of the real boards, there are never enough numbers of the board available for the testing. Sometimes, the mark-up boards are employed to replace the real boards. Even so, the dummy boards (or fillers) are also often used in the full scale thermal tests due to lack of the mark-up boards available. The filler must have a proper flow resistance to simulate the pressure drop of the individual boards. Occasionally, the empty slots with flow restriction devices such as orifices are in place of the dummy boards in the thermal analysis or tests.

The understanding of the effect of the surrounding boards on the component temperatures of the target board is very critical. This is especially true for the effect of the empty slots in the card cage on the thermal analysis and the tests. Similarly, the fillers are frequently employed during the system thermal tests to insure the proper flow distribution to all slots (or boards).

The purpose of this study is to examine the effect of filler on the component temperatures of the target board under active (forced convection) and passive (natural convection) cooling.

Since the component temperatures on a given board will be affected by the presence of neighboring boards. Therefore, the concept of employing 3 detailed boards as a group is proposed in the final analysis and test. The target board is sandwiched by two real (detailed) boards. The pressure drop or flow resistance calculated from the board level analysis should be applied to the rest of other boards in the system. For the board located at both ends next to the walls of the card cage, 2 boards (the target board and the neighbor board) will be needed in the final analysis. The component temperatures obtained for the target board are considered to be the final results. The analysis should be repeated by rotating 3-board group throughout the entire system for the complete solution of the system. This 3-board concept provides an efficient way to obtain the accurate solution. This is because this concept significantly reduces the size of the thermal model needed to obtain the accurate results but more importance is that these two neighbor boards provide the correct boundary conditions such as the flow field and heat load to the target board.

2. Thermal Analysis

The thermal analysis is performed on two cases. One is under active cooling with forced convection and another is subjected to passive cooling under natural convection.

2.1 Forced convection air cooling

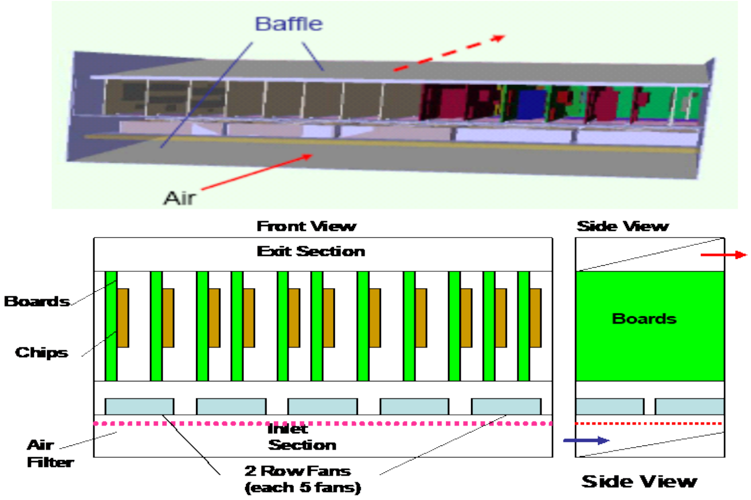


Figure 1 Active Air Cooled System

The system under consideration is a low profile shelf which has 10 fans placed in two rows. The sketch along with the thermal model of the system is given in Figure 1. The CFD analysis is performed for both cases. One is with fully filled card cage with 3-board (Case A) and another is partially filled card cage with 3-board (Case B) as shown in Figures 2 and 3 respectively. The target board is sandwiched by two neighbor boards. This arrangement is needed to insure the correct flow filed and heat load to the target board which will be affected by the neighbor boards.

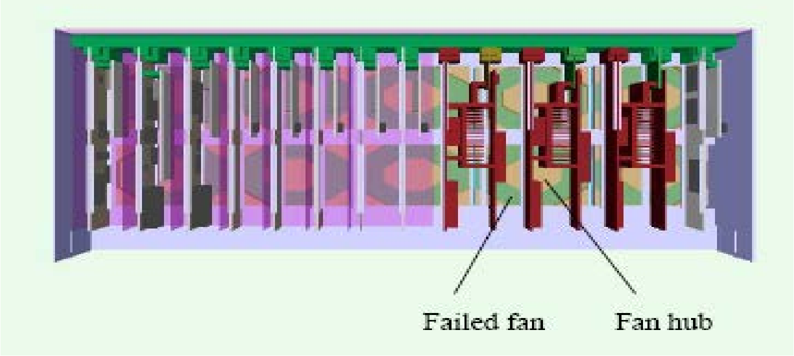


Figure 2 Fully Filled Card Cage with 3-Board

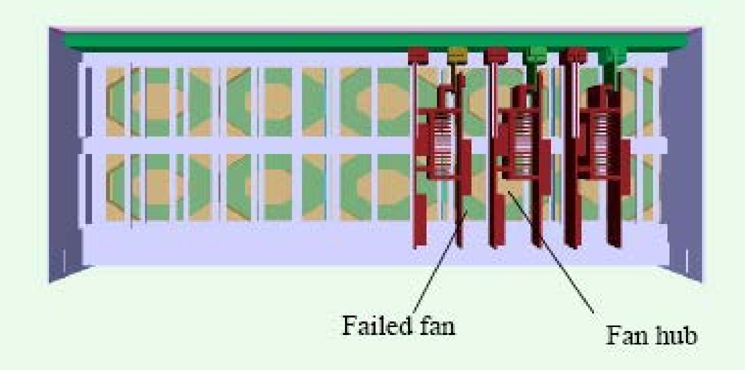


Figure 3 Partially Filled Card Cage with 3-Board

2.2 Natural convection air cooling

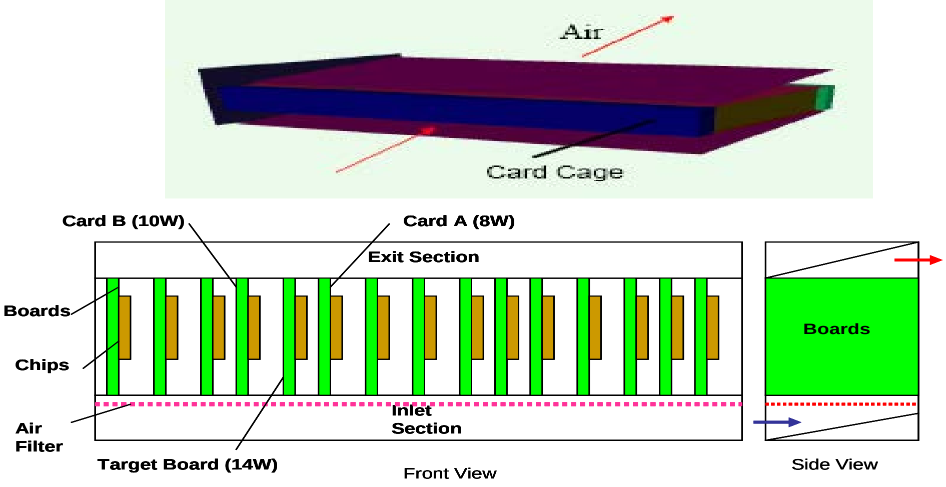


Figure 4 Passive Air Cooled System

The previous discussion is limited to the forced air cooling with the fans in the system. The attention is now turned to the equipment without the fan. The components on the board in such a system are subjected to the thermal radiation and natural convection. The passive cooling is simple, cost effective and reliable. The system under consideration as shown in Figure 4 is a 4U shelf which includes 15 2U boards (1U = 1.75” high). The shelf without the fan is cooled by natural convection. Thermal radiation effect must always be included in the thermal analysis under a passive cooling condition.

3. Results and Discussion

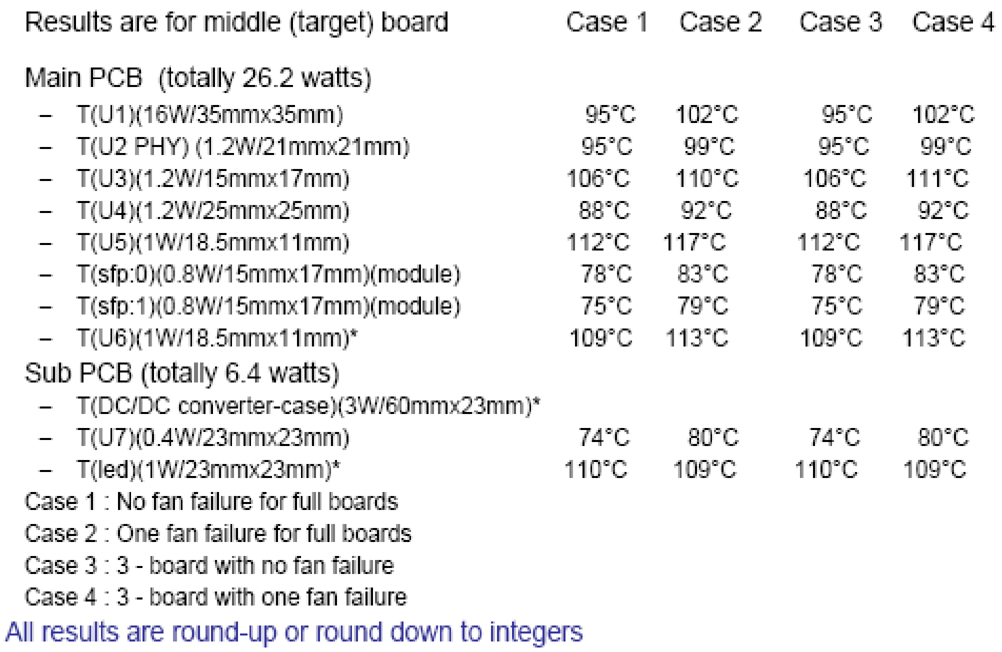
3.1 Forced convection air cooling

The thermal analysis is performed on two physical configurations. One is with fully filled card cage (Case A) and another is partially filled card cage with 3-board card (Case B). In addition to the normal operation with all fans on, GR-63 requires the component temperature should also meet their respective temperature limits under one fan failure condition. Therefore, CFD analysis is done for a total of four cases.

The component temperatures of two configurations (4 cases) are presented in Table 1. As can be seen from the table, there are no noticeable difference in the predicted results for the target board between Cases A and B (with empty slots in the shelf) in the normal operation (all fans on) and one fan failed condition.

The results indicate that the target board is very insensitive to the operation conditions in far away locations. In other words, the results of the target boards are relatively independent of the performance of the other boards and fans located at the distance from the boards under consideration. The main reason is that the board thermal performance is generally governed by the fans directly located under or above the boards under consideration. In this particular case, the fans are located so closed to the card cage that the air flow distribution to the boards is directly linked to the fans right below the board under consideration. The effect of one fan failure is generally a local phenomenon and only the board direct above the failed fan will be affected.

Table 1 Component Junction Temperatures for Full Boards and 3-Board Configurations



Results are for middle (target) board	Case 1	Case 2	Case 3	Case 4
Main PCB (totally 26.2 watts)				
– T(U1)(16W/35mmx35mm)	95°C	102°C	95°C	102°C
– T(U2 PHY) (1.2W/21mmx21mm)	95°C	99°C	95°C	99°C
– T(U3)(1.2W/15mmx17mm)	106°C	110°C	106°C	111°C
– T(U4)(1.2W/25mmx25mm)	88°C	92°C	88°C	92°C
– T(U5)(1W/18.5mmx11mm)	112°C	117°C	112°C	117°C
– T(sfp:0)(0.8W/15mmx17mm)(module)	78°C	83°C	78°C	83°C
– T(sfp:1)(0.8W/15mmx17mm)(module)	75°C	79°C	75°C	79°C
– T(U6)(1W/18.5mmx11mm)*	109°C	113°C	109°C	113°C
Sub PCB (totally 6.4 watts)				
– T(DC/DC converter-case)(3W/60mmx23mm)*				
– T(U7)(0.4W/23mmx23mm)	74°C	80°C	74°C	80°C
– T(led)(1W/23mmx23mm)*	110°C	109°C	110°C	109°C

Case 1 : No fan failure for full boards
Case 2 : One fan failure for full boards
Case 3 : 3 - board with no fan failure
Case 4 : 3 - board with one fan failure

All results are round-up or round down to integers

3.2 Natural convection air cooling

The shelf without the fan is cooled by natural convection. Thermal radiation effect must always be included in the thermal analysis for a passive cooling condition. The purpose of the analysis is to examine the effects of the empty slots or the fillers on the temperature of the components of the target board. The CFD analysis is first performed on the fully filled heated boards in the system is shown in Figure 5 and the results are given in Figure 6. The maximum component temperature for the target board is 122 °C and for two neighbor boards are 112 °C and 114 °C for Cards A and B, respectively. These results are considered to be the baseline values

The next step is to turn off the power to all the boards with exception of the target board and Cards A and B. The thermal model and results for the 3-heated board in the fully filled card cage are given in Figures 7 and 8, respectively. Due to radiation, heat is transferred from the heated boards to the zero power boards which results in significant reduction of the temperature of the components on the 3 powered boards. In addition, the temperature for those zero power boards decreases as the distance from the heated boards increasing.

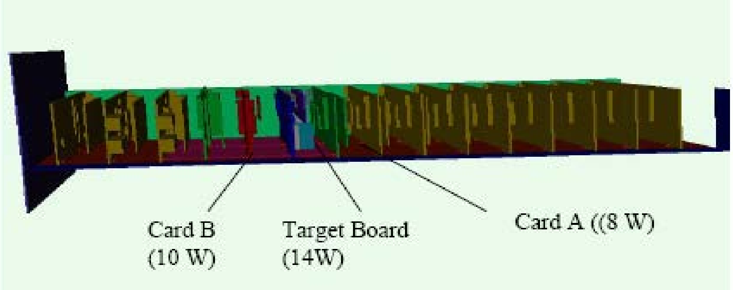


Figure 5 Fully Filled Heated card cage with 3-board model of System

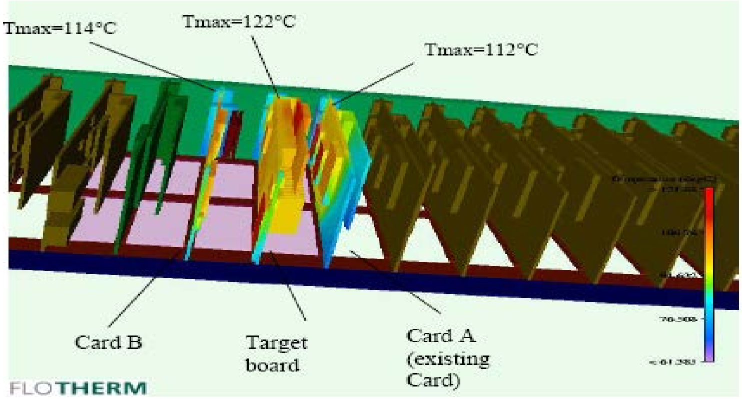


Figure 6 Results for Fully Filled Heated Boards in System

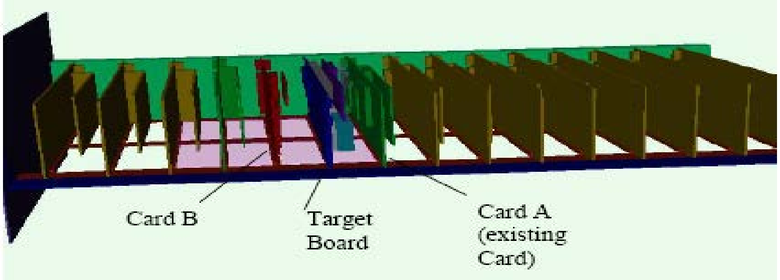


Figure 7 Thermal Model for 3 Detailed Boards with Rest of Zero Power Boards

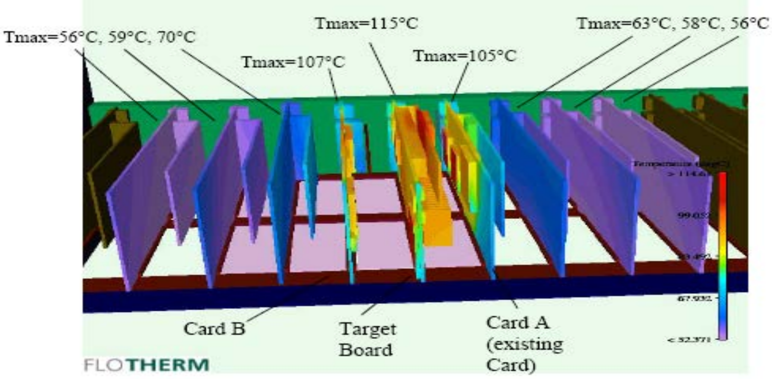


Figure 8 Results for 3 Detailed Boards with Rest of Zero Power Boards

The analysis is further extended to the case without the zero power fillers in the card cage as shown in Figure 9 In other words, all zero power cards in the above case are removed and the card cage only has 3 heated boards plus a lot of empty slots. The component temperatures on the target board and Cards A and B are presented in Figure 10. As can be seen from Figures 8 and 10, no noticeable difference on component temperatures of the target board between partially filled card cage (3cards only) and fully filled card cage with zero power fillers under natural convection However, the temperatures of Cards A and B are slightly higher (by less than 1 ºC) for the former (only 3 boards in the card cage). The main reason is that the small heat transfer coefficient from the surfaces of Cards A and B located at opposite to the target board which are exposed to a near stationary large pool of air in an open space. On the other hand, a slightly higher heat transfer coefficient is obtained because air is circulating and flowing through the spaces between the boards as illustrated in Figure 8.

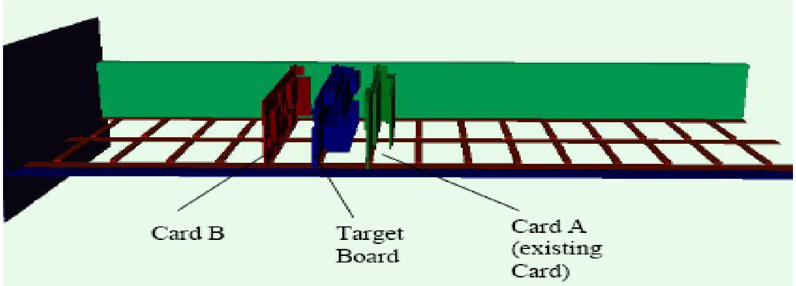


Figure 9 Thermal Model of 3-Heated-board Card Cage without Fillers

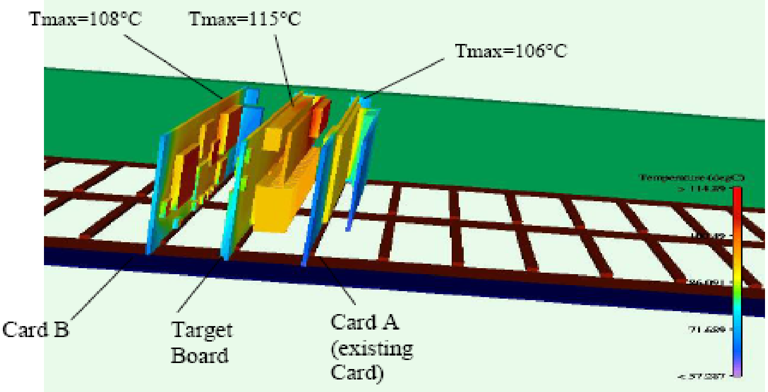


Figure 10 Results for 3-Heated-board Card Cage without Fillers

4. Summary and Conclusion

The proposed 3-board concept provides an efficient way to obtain the accurate solution. This concept significantly reduces the size and running time of the thermal model needed to obtain the complete and accurate results because these two neighbor boards provide the correct boundary conditions such as the flow field and temperature profile of air for the target board.

Examining all results given in this section, the effects of fillers can be summarized as follows:

1) Forced Air Cooled Systems

No noticeable difference in the component temperatures between the cases of the fully loaded and partially filled card cages under the forced air cooling with the fans. The main reason is that no mixing of air flow from fan exits to the card cage due to the limited space existing between the card cage and the fan tray. Furthermore, the thermal results of the individual boards are generally governed by the performance of the fans directly located below or above.

2) Passive Cooled Systems

Examining Figures 8 and 10 in details reveals no significant difference in the component temperatures between the cases with the zero power fillers and the empty slots under the natural convection conditions. However, both cases significantly reduce the component temperatures of the heated boards as compared with the fully heated card cage. Therefore, the thermal simulations and/or tests for the passive cooling should be conducted under the actual operation conditions with the full power on all boards in the card cage.

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