## CONTENTS

**CHAPTER 1  INTRODUCTION**  
1.1 Base Transceiver Station (BTS)  
1.2 Thermal Design of BTS  
1.3 Boundary Conditions for Analysis  
1.4 Selection of Suitable Modeling Software  

**CHAPTER 2  LITERATURE SURVEY**  
2.1 Background and Motivation  
2.2 Challenges for Electronics Thermal Management  
2.3 Air flow Management  
2.3.1 Fan Selection  
2.3.2 Effect of air density on fan performance  
2.3.3 Fan Scaling  
2.4 Active Cooling Technologies  
2.4.1 Micro Channel Concepts  
2.4.2 Facility and Rack Cooling  
2.5 Passive Cooling Technologies  
2.6 Overview of Thermal Modeling in Electronics Systems  
2.7 Uncertainty Analysis  
2.8 Computational Modeling of MOSFETs  
2.9 Altitude Studies  
2.10 Source of Acoustic Noise
CHAPTER 3  EXPERIMENTAL TEST SETUP  

3.1  Thermal Validation Test  
3.1.1  Test Equipment for Thermal Validation  
3.1.2  Thermal Validation Test Procedure  
3.1.3  Thermal Test Procedure  
3.1.4  Environmental Chamber Specification  

3.2  Instrumentation for Flow Measurement  
3.2.1  Fan Performance Curve Measurement  
3.2.2  System Impedance Testing  
3.2.3  Heat Sink Thermal Resistance  

3.3  Operational Vibration Test Setup  
3.3.1  Sinusoidal Vibration Test  
3.3.2  Random Vibration  
3.3.3  Sine Dwell Test
3.3.4 Test Procedure

3.4 Shock Test

3.5 Acoustic Noise Test

3.5.1 Environmental Condition

3.5.2 Test Configurations

3.5.3 Mode of Operation

3.5.4 Acoustic-Sound Power Test

3.5.5 Test and Measurement Equipment

3.5.6 Test Specification

3.5.7 Test Setup

3.5.8 Test Procedure

<table>
<thead>
<tr>
<th>CHAPTER 4</th>
<th>INVESTIGATIONS INTO THERMAL LOAD MANAGEMENT OF BTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Geometric Model of BTS</td>
<td></td>
</tr>
<tr>
<td>4.2 Thermal Design Methodology</td>
<td></td>
</tr>
<tr>
<td>4.2.1 Thermal Model Inputs</td>
<td></td>
</tr>
<tr>
<td>4.2.2 Mechanical Model Considerations</td>
<td></td>
</tr>
<tr>
<td>4.3 PCB Layout &amp; Components Power Dissipation</td>
<td></td>
</tr>
<tr>
<td>4.3.1 System Board (SB) layout</td>
<td></td>
</tr>
<tr>
<td>4.3.2 SB and PIU component power details</td>
<td></td>
</tr>
<tr>
<td>4.3.3 Base Band Board layout (BB)</td>
<td></td>
</tr>
<tr>
<td>4.3.4 Base Band component power details</td>
<td></td>
</tr>
<tr>
<td>4.3.5 Power board Layout (PB)</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 5 INVESTIGATIONS OF VARIOUS METHODS FOR DESIGN OF BTS

5.1 BTS Design Without Conduction Path

5.1.1 Temperature Contours of System Board
5.1.2 Temperature contours of BB
5.1.3 Temperature contours of PB
5.1.4 Temperature contours of Chassis
5.1.5 External ambient temperature distribution
5.1.6 Velocity profile
5.1.7 Fan Operating Point
5.1.8 Summary of the results
5.1.9 Observations and recommendations for the preliminary design
5.1.10 Coupling details SB, BB, PB

5.2 BTS Design With Conduction Path

5.2.1 Temperature contours of SB
5.2.2 Temperature contours of BB
5.2.3 Temperature contours of PB
5.2.4 Temperature contours of Chassis
5.2.5 Internal ambient temperature distribution 102
5.2.6 External ambient temperature distribution 103
5.2.7 Velocity profile 103
5.2.8 Fan Operating Point 104
5.2.9 Summary of the results 105
5.2.10 Observations and recommendation with heat towers 107
5.3 BTS Design With Fan Failure Condition For 3*60mm 108
  5.3.1 Observations of Fan fail condition in SB and PIU 109
  5.3.2 Observations of Fan fail condition in BB 110
  5.3.3 Observations of Fan fail condition in PB 111
5.4 BTS Thermal Design With 2*92mm Fan 112
  5.4.1 Thermal model 112
  5.4.2 Thermal Model Considerations 113
  5.4.3 Mechanical Model Considerations 113
  5.4.4 Fan details (92mm) considered for thermal simulation 113
  5.4.5 Temperature contour details of SB 114
  5.4.6 Observations on Exit Air Temperature and Chassis
      Temperature 116
  5.4.7 Flow Distribution Pattern 117
  5.4.8 Fan Operating curve 118
  5.4.9 Comparison of Simulation Results with 3*60
      &2*92mm Fan 119
5.4.10 Observations with 92mm Fan
5.4.11 Fan comparison details

5.5 BTS Design For Fan Failure Condition With 2*92mm Fan Assembly

5.5.1 Analysis on Fan fail condition in SB and PIU

5.6 Observations Of Fan Fail Condition In BB

5.6.1 Observations of Fan fail condition in PB

5.7 BTS Thermal Design With 3*92mm Fan Assembly

5.7.1 Thermal model

5.7.2 Thermal Model Considerations

5.8 Temperature Contour Details

5.8.1 Observations on Exit Air Temperature and Chassis Temperature

5.8.2 Air flow Distribution

5.8.3 Fan Operating curve

5.8.4 Summary – Simulation results of 3*92mm fan Assembly

5.8.5 Comparison between 3*92mm and 2*92mm fan

5.8.6 Observations with 3*92mm Fan

5.9 Fan Failure condition for 3*92mm Fan Assembly

5.9.1 Observations of fan failed conditions in 3*92 mm Fan assembly

5.10 BTS Thermal Design With Speed Reduction Of 92mm Fan

5.10.1 Details of 60mm and 92mm fan
5.10.2 Assumptions for present analysis
5.10.3 Procedure
5.10.4 Temperature Results
5.10.5 Fan operating point
5.10.6 Observations
5.11 Thermal Validation of BTS
5.11.1 Test Configuration
5.11.2 System Configuration for 92 mm Fan Assy
5.11.3 Temperature measurement with 92 mm fan assy
5.11.4 Thermal Validation Test Procedure
5.11.5 Thermal Validation Test Results with 92 mm Fan Assy
5.11.6 Thermal Validation Results and Discussions of 92 mm fan assy

CHAPTER – 6 ANALYSIS ON BTS DESIGN USING PIU-A
6.1 PIU-A Modelling Inputs & Assumptions
6.1.1 Mechanical Model Considerations
6.1.2 PIU-A PCB layout
6.1.3 Layer stack up details for PIU-A
6.1.4 Power dissipation details for BTS with PIU-A
6.1.5 Fan Details for BTS system for PIU-A Thermal design
6.1.6 Thermal design approach of PIU-A with BTS mechanics
6.2 PIU-A Thermal Design Without Cooling Plate
6.2.1 Temperature profile of PIU-A
6.2.2 Summary of the results without cooling plate 173
6.2.3 Observations and Recommendations without cooling plate 174
6.2.4 Cooling plate approach for PIU-A board 175

6.3 PIU-A Thermal Design With Cooling Plate (All Fans Running) 177
6.3.1 Temperature profile of PIU-A PIU 177
6.3.2 Temperature profile of the cooling plate 178
6.3.3 Internal ambient temperature distribution 179
6.3.4 Velocity profile with BTS mechanics 179
6.3.5 Fan operating point for 60% speed with all fans running 180
6.3.6 Summary of the temperature results with cooling plate 181
6.3.7 Observations with cooling plate for all fans running 181

6.4 PIU-A Thermal Design With Cooling Plate (Left Fan Failure) 182
6.4.1 Temperature profile of PIU-A PIU 183
6.4.2 Temperature profile of the cooling plate 183
6.4.3 BTS chassis thermal profile with PIU-A 184
6.4.4 Internal ambient temperature distribution 185
6.4.5 Velocity profile with BTS mechanics 186
6.4.6 Summary of the results with cooling plate 187
6.4.7 Observations with cooling plate for Left fan fail 187

6.5 Cooling Plate Optimisation Design 188
6.5.1 Thermal Model Considerations for optimised design 188
6.5.2 Mechanical Model Considerations 189
6.5.3 PIU-A PCB final layout 189
6.5.4 Layer stack up and thermal vias details 190

6.6 PIU-A Optimised Thermal Design With Left Fan Failure 193
6.6.1 Cooling plate details 193
6.6.2 Temperature profile of PIU-A PIU 196
6.6.3 Temperature profile of the cooling plate 197
6.6.4 Air temperature profile in the PIU 198
6.6.5 Velocity profile in the PIU 198
6.6.6 Summary of results with cooling plate 199
6.6.7 Observations of Optimised case with left fan fail 199

6.7 PIU-A Optimised Thermal Design With All Fans Running 200
6.7.1 Temperature profile of PIU-A PIU 200
6.7.2 Temperature profile of the cooling plate 201
6.7.3 Internal ambient temperature distribution 202
6.7.4 Velocity profile with BTS mechanics 203
6.7.5 Fan operating point for 60% speed with all fans running 203
6.7.6 Summary of the results with cooling plate 204
6.7.7 Observations of optimised case with all fans running 205

6.8 PIU-A Thermal Validation 205
6.8.1 Test Configuration 205
6.8.2 Temperature measurement of PIU-A with 92 mm fan assy 206
6.8.3 Thermal Validation Test Results of PIU-A with 92 mm Fan Assy 208
6.8.4 Thermal Validation Results and Discussions of PIU-A 208
6.8.5 Thermal Validation conclusion with PIU-A 209

CHAPTER – 7 STRUCTURAL AND ACOUSTIC VALIDATION

TESTS FOR EVALUATED BTS 210

7.1 Operational Vibration Test Report 210

7.1.1 Unit Set up & Location of Acceleration sensor during Vibration test. 211

7.1.2 Sinusoidal Vibration with Test Graphs 212
7.1.3 Random Vibration 217

7.2 Shock 221

7.3 Shock/Vibration Test Result 225

7.4 Acoustic Validation 225

7.4.1 Test Configurations 225
7.4.2 Mode of Operation 225
7.4.3 Acoustic - Sound Power Test 226
7.4.4 Test Specification 226
7.4.5 Test Results 227
7.4.6 Acoustics Test Graphs 245

CHAPTER - 8 CONCLUSIONS 257

SCOPE OF FUTURE WORK 263

REFERENCES 264