

# 5G RAN Debugging Benchmark Problem2

## Scenario Overview

You are a senior RF engineer at a Tier-1 telecommunications operator. Multiple customers have reported poor user experience and connection issues in a specific geographic area where you recently upgraded from LTE to 5G NR (New Radio). Complaints include slow data rates, connection drops, and inability to maintain consistent service when moving within the coverage area. Your task is to diagnose and resolve the issue.

## System Configuration

- **Base Station:** Nokia AirScale 5G Base Station
- **Cell Configuration:** 3-sector site (Alpha, Beta, Gamma sectors)
- **Frequency Band:** n78 (3.5 GHz TDD)
- **Bandwidth:** 100 MHz
- **Subcarrier Spacing:** 30 kHz
- **MIMO Configuration:** 64T64R Active Antenna System
- **Neighboring Technologies:** Co-located LTE (Band 7, 2600 MHz)
- **Backhaul:** 10 Gbps fiber connection to regional data center
- **Core Network:** SA (Standalone) configuration
- **Software Version:** AirScale System Module 22.Q4

## Observed Problems

1. Average throughput in the Beta sector has decreased by 65% over the past week
2. SINR measurements have degraded from average 18 dB to 7 dB in affected sector
3. Call drop rate increased from 0.5% to 4.7%
4. Beta sector shows higher resource block utilization (85%) compared to Alpha (40%) and Gamma (45%) sectors
5. OSS alarms show occasional "Cell Unavailable" errors for Beta sector, each lasting 2-3 minutes

## Available Data

### KPI Reports

Unset

Sector	Throughput (Mbps)	# Active Users	RB Utilization	RACH Success	Handover Success
Alpha	658	27	40%	98.7%	99.2%

Beta	187	32	85%	
87.3%	82.6%			
Gamma	612	30	45%	
99.1%	98.9%			

## Log Excerpt (Beta Sector)

Unset

```
2025-05-10T09:23:44.723 [WARNING] B5G-NODE-12-BETA: TxPower
measured at RF unit port (36.2 dBm) below expected value (43.0
dBm)
2025-05-10T09:25:18.104 [ERROR] B5G-NODE-12-BETA: VSWR threshold
exceeded (3.7, limit 2.5)
2025-05-10T09:25:20.330 [WARNING] B5G-NODE-12-BETA: RRU
temperature high (62°C)
2025-05-10T09:28:47.552 [INFO] B5G-NODE-12-BETA: Cell restarted
successfully
2025-05-10T09:46:12.178 [WARNING] B5G-NODE-12-BETA: Thermal
protection active, TxPower limited by 6dB
2025-05-10T10:12:33.905 [ERROR] B5G-NODE-12-BETA: VSWR threshold
exceeded (3.9, limit 2.5)
2025-05-10T11:05:21.476 [WARNING] B5G-NODE-12-BETA: Active
cooling fan #2 RPM low (1200, expected 2800)
```

## Spectrum Analysis

- No significant external interference detected in n78 band
- Periodic power drops observed in Beta sector transmission
- Spectrum occupancy appears normal
- No significant PIM (Passive Intermodulation) detected

## Site Information

- Tower height: 45 meters
- Last physical maintenance: 3 months ago
- Weather conditions: Clear, temperature 28°C
- Recent work: Antenna system upgraded to 64T64R AAS 2 weeks ago

## Debugging Task

Analyze the information provided and:

1. Identify the most likely root cause(s) of the performance degradation
2. Explain your reasoning using the available data
3. Outline a step-by-step troubleshooting plan to confirm your diagnosis

4. Recommend immediate actions to restore service
5. Suggest preventative measures for avoiding similar issues in the future

Your analysis should include consideration of:

- RF path issues
- Hardware problems
- Configuration errors
- Environmental factors
- Interaction between 5G and co-located LTE

## **Evaluation Criteria**

Answers will be evaluated based on:

1. Accuracy of root cause identification
2. Technical depth and understanding of 5G RAN technology
3. Logical reasoning and methodical approach to troubleshooting
4. Prioritization of immediate vs. long-term solutions
5. Completeness of the proposed resolution plan

# Response-1 [Qwen3:32B-Q8 on RHOCp with RTX 4090 OnPremise] from AliBaba

OI qwen3:32b-q8\_0 Today at 4:54 PM

Thought for 46 seconds ▾

## Root Cause Analysis

### Primary Root Causes:

- Hardware Degradation in RF Path (Antenna/Cable/RRU):**
  - High VSWR (Voltage Standing Wave Ratio):** Repeated VSWR threshold exceedances (3.7–3.9 vs. 2.5 limit) indicate an impedance mismatch in the RF path. This is likely due to a damaged antenna element, faulty RF cable, or degraded connectors in the Beta sector. The recent 64T64R AAS upgrade increases the likelihood of installation-related issues (e.g., misalignment, improper termination).
  - Thermal Overload:** Elevated RRU temperature (62°C) and low fan RPM (1200 vs. 2800 expected) suggest a cooling system failure. Overheating triggers thermal protection, reducing transmit power (TxPower limited by 6dB) and compounding signal degradation.
- Interconnected Effects:**
  - Reduced TxPower and Signal Quality:** Low TxPower (36.2 dBm vs. 43.0 dBm expected) and thermal throttling degrade downlink signal strength, leading to lower SINR (7 dB vs. 18 dB baseline) and higher retransmission rates. This explains the high RB utilization (85%) and poor throughput (187 Mbps vs. Alpha/Gamma at 658/612 Mbps).
  - Call Drops and Handover Failures:** Poor SINR and unstable TxPower cause unstable connections, resulting in a 4.7% call drop rate and 82.6% handover success rate in Beta.

## Technical Reasoning

- VSWR and RF Path Issues:** High VSWR reflects power back to the RRU, reducing effective radiated power and increasing heat. This creates a feedback loop: poor signal quality → higher retransmissions → higher RB utilization → increased heat → thermal throttling.
- Thermal Management Failure:** The low fan RPM (Fan #2) indicates a hardware fault in the cooling system. Overheating exacerbates TxPower limitations and risks permanent RRU damage.
- Post-Upgrade Complications:** The 64T64R AAS installation likely introduced configuration or physical layer issues (e.g., incorrect tilt, damaged feeders, or waterproofing gaps), which are now manifesting as VSWR and thermal problems.

## Step-by-Step Troubleshooting Plan

- Immediate Diagnostics:**
  - Check Alarms:** Confirm active VSWR, thermal, and fan alarms via OMC/NMS.
  - RF Path Inspection:** Visually inspect Beta sector's antenna, RF cables, and connectors for physical damage, moisture ingress, or poor termination.
  - VSWR Measurement:** Use a VSWR tester to isolate the faulty component (antenna vs. cable).
  - Thermal Imaging:** Scan RRU and antenna for hotspots indicating overheating or blocked airflow.
- Hardware Verification:**
  - Fan and Cooling System:** Test Fan #2's functionality and replace if defective. Verify thermal sensor calibration.
  - RRU Health Check:** Run diagnostics on the RRU's power amplifiers and temperature sensors to rule out internal faults.
  - Antenna Performance Test:** Validate beamforming alignment and element health using AAS test tools.
- Configuration Review:**
  - TxPower Settings:** Ensure configured TxPower matches hardware capabilities and thermal thresholds.
  - Cooling System Configuration:** Verify fan control logic and temperature thresholds in the RRU firmware.
- Long-Term Monitoring:**
  - KPI Trending:** Monitor SINR, RB utilization, and temperature post-repair to confirm resolution.
  - Periodic VSWR Checks:** Schedule quarterly VSWR tests for all sectors to preemptively identify RF path issues.

## Immediate Actions to Restore Service

### 1. Temporarily Reduce Load:

- Limit Beta sector's active users or redirect traffic to Alpha/Gamma via load balancing to reduce RB utilization and thermal stress.

### 2. Activate Redundant Cooling:

- If the RRU has redundant fans, prioritize power to remaining functional fans to mitigate overheating.

### 3. Replace Faulty Components:

- Replace damaged RF cables, connectors, or the antenna if VSWR issues persist. Replace Fan #2 immediately.

### 4. Thermal Protection Override (Temporary):

- If TxPower reduction is the only active thermal protection, temporarily disable it (with caution) to restore signal strength while repairs are underway.
- 

## Preventative Measures

### 1. Post-Upgrade QA Process:

- Implement mandatory RF path validation (VSWR, TxPower, beam alignment) after hardware upgrades.
- Use automated tools to compare pre/post-upgrade KPIs for anomalies.

### 2. Environmental Hardening:

- Apply waterproofing to all RF connectors and inspect for corrosion during maintenance.
- Ensure proper cable routing to avoid mechanical stress on connectors.

### 3. Proactive Maintenance:

- Schedule quarterly thermal checks and fan health diagnostics for all RRUs.
- Monitor VSWR trends to detect early signs of RF degradation.

### 4. Cooling System Redundancy:

- Design RRUs with N+1 fan redundancy to tolerate single-fan failures without overheating.

### 5. Training and Documentation:

- Train field engineers on 64T64R AAS installation best practices, including VSWR troubleshooting and thermal management.
- 

## Summary

The Beta sector's performance degradation stems from a combination of **RF path faults (high VSWR)** and **thermal management failure (fan defect)**, likely introduced during the AAS upgrade. Immediate hardware replacement and thermal mitigation are critical to restore service, while process improvements will prevent recurrence. This case highlights the importance of rigorous post-deployment testing and proactive monitoring in 5G RAN operations.

# Response-2 [Gemma3:27B-Q8 on RHOCF with RTX 4090 OnPremise] from Google

gemma3:27b-it-q8\_0 Today at 4:58 PM

## 5G RAN Debugging: Cell Sector Performance Degradation - Analysis & Resolution

Here's an analysis of the provided data, identifying the likely root cause, reasoning, troubleshooting plan, and recommendations to restore service and prevent future occurrences.

### 1. Most Likely Root Cause(s):

The primary root cause is **hardware failure and thermal issues within the Beta sector's Remote Radio Unit (RRU)**, specifically impacting the RF transmission chain. A secondary contributing factor is potentially a mismatch or improper configuration related to the newly upgraded 64T64R AAS system.

### 2. Reasoning:

Several pieces of evidence point to this conclusion:

- **Log Excerpts:** The Beta sector logs are filled with warnings and errors indicating:
  - **Low Tx Power:** The measured transmit power is significantly below the expected value.
  - **High VSWR:** A high Voltage Standing Wave Ratio indicates a mismatch in the RF transmission line, likely due to a component failure or degradation within the RRU.
  - **High RRU Temperature:** Elevated temperatures exacerbate component failures and can trigger thermal protection, reducing transmit power.
  - **Active Cooling Fan Issues:** A malfunctioning cooling fan further contributes to the thermal problem.
  - **Cell Restarts:** Frequent cell restarts point to instability likely caused by hardware failure and thermal shutdown.
- **KPI Degradation:** The 65% throughput drop, degraded SINR, and increased call drop rate are all symptoms of a compromised RF transmission chain. High RB Utilization suggests the sector is trying to compensate for the signal degradation by using more resources.
- **Correlation with Upgrade:** The performance degradation started around the time of the 64T64R AAS upgrade, suggesting a potential installation issue, hardware defect with the new system, or a configuration incompatibility.
- **Spectrum Analysis:** While no interference or PIM are detected, the observed "periodic power drops" directly support the idea of a failing RRU.
- **Lack of External Factors:** The absence of external interference and PIM effectively rules out these issues as primary contributors.

The combination of these factors strongly suggests a hardware failure within the Beta sector RRU, compounded by a thermal issue.

### 3. Step-by-Step Troubleshooting Plan:

1. **Immediate Verification (Remote):**
  - **Detailed Log Review:** Examine the logs for patterns and specific error codes related to the RRU components (PA, Combiner, Filters, etc.).
  - **Real-time Performance Monitoring:** Monitor the Beta sector's throughput, SINR, RB utilization, and call drop rate *in real-time* to observe the pattern of performance degradation. Correlate this with RRU temperature and transmit power readings.
  - **Remote RRU Control:** If possible, attempt to remotely cycle the RRU's power or trigger a self-test. Monitor the results.
2. **On-Site Physical Inspection (Priority 1):**
  - **Visual Inspection:** Check the RRU for any visible signs of damage (e.g., burnt components, bulging capacitors).
  - **Temperature Readings:** Use a thermal camera to map the temperature distribution on the RRU to identify hot spots.
  - **Connector Inspection:** Inspect all RF connectors (antenna, feeder cable, RRU) for corrosion, loose connections, or damage. Perform a VSWR sweep on each connector.
  - **Cooling System Check:** Verify the functionality of all cooling fans and ensure proper airflow. Check for dust buildup obstructing airflow.
  - **Power Supply Check:** Verify the RRU is receiving stable and correct power.
3. **Component-Level Testing (if possible/trained technician):**
  - **PA/Combiner Testing:** If accessible, use RF test equipment to measure the output power and linearity of the Power Amplifier (PA) and Combiner.
  - **Filter Testing:** Check the insertion loss and return loss of the filters.
4. **Configuration Verification:**
  - **Software Version:** Confirm the AirScale software version is the recommended version for the upgraded hardware.
  - **Calibration Data:** Verify that the calibration data for the 64T64R AAS is correctly loaded and applied to the system.
  - **Antenna Alignment:** Double-check the physical alignment of the 64T64R antennas, ensuring they are pointing in the correct direction and are properly phased.





#### 4. Immediate Actions to Restore Service:

1. **If RRU is deemed faulty:** Replace the RRU with a known-good spare unit. This is the most likely and fastest resolution.
2. **If cooling issue is identified:** Immediately address the cooling problem (e.g., replace faulty fan, clean vents).
3. **Temporary Power Reduction:** As a temporary measure, if replacing the RRU is not immediately possible, reduce the transmit power of the Beta sector to mitigate the thermal protection triggering. *This will impact coverage and capacity but may stabilize the cell.*
4. **Traffic Re-steering (If Available):** If possible, re-steer traffic from the Beta sector to the Alpha and Gamma sectors to minimize the impact on users.

#### 5. Preventative Measures for Avoiding Similar Issues in the Future:

1. **Thorough Testing:** Implement a rigorous testing procedure after *any* hardware upgrade or software change. This should include functional testing, performance testing, and environmental stress testing.
2. **Preventive Maintenance:** Establish a regular preventive maintenance schedule for all base station equipment, including cleaning, inspection, and component replacement.
3. **Environmental Monitoring:** Install temperature and humidity sensors in the equipment shelter to monitor environmental conditions.
4. **Alarm Thresholds:** Adjust alarm thresholds to be more sensitive to early warning signs of equipment failure (e.g., slightly elevated temperature, minor VSWR increase).
5. **Vendor Collaboration:** Work closely with the equipment vendor (Nokia) to ensure proper installation procedures, software updates, and troubleshooting support.
6. **Spares Management:** Maintain an adequate inventory of critical spare parts (especially RRUs, power supplies, and cooling fans) to minimize downtime.
7. **Training:** Ensure that field technicians are properly trained on the installation, maintenance, and troubleshooting of the 5G RAN equipment.

This comprehensive approach will help diagnose the root cause, restore service quickly, and prevent future issues, ensuring a reliable 5G experience for subscribers.

## AI as a Judge (AlaaJ) Overall Assessment (By Sonet 3.7)

### Overall Assessment

Both responses demonstrate excellent understanding of 5G RAN technology and provide thorough diagnostic approaches. The key differences:

1. **Technical Explanation:** Response 1 provides a more detailed explanation of the interconnected nature of the issues and how they create a self-reinforcing cycle of degradation
2. **Troubleshooting Structure:** Response 2 offers a slightly more structured progression from remote to on-site inspection to component-level testing
3. **Preventative Measures:** Response 2 provides more extensive preventative measures, including environmental monitoring and alarm threshold adjustments

Both responses would be highly effective for addressing the problem, with Response 1 having a slight edge in technical depth and cause-effect explanation, while Response 2 excels in methodical troubleshooting structure and preventative measures.