

## Discussion on High Power Attenuator Failure and Prevention Guide

Through our dozens of years of market feedback and technical experience, we have observed that failures in RF coaxial fixed attenuators predominantly occur in the  $\geq 200$  W( CW) power range. The vast majority of these failures manifest as burnt-out internal resistor elements. This article is to address causes of failure, failure symptoms, and preventive countermeasures, also we have elaborated why it is important to monitor the case temperature.

### 1. Causes of Failure in High-Power Attenuators $\geq 200$ W

#### 1.1 Thermal Management Failure

The fundamental cause of failure in high-power attenuators ( $\geq 200$ W) is inadequate thermal management. For example, with a 200W input signal and 30 dB attenuation, approximately 199.8 W of power is dissipated as heat within the device. If this heat cannot be effectively dissipated—due to factors such as insufficient airflow, or poor contact between the mounting surface and the attenuator housing, heat will accumulate rapidly, leading to thermal destruction of the internal resistive elements.

#### 1.2 Impedance Mismatch (High VSWR)

When the system connected to the attenuator exhibits a high Voltage Standing Wave Ratio (VSWR), a portion of the incident power is reflected back toward the attenuator. This increases the actual power dissipation beyond the nominal input level, significantly raising the risk of overload and thermal failure.

#### 1.3 Signal Type

Pulsed Signals: High peak power (pulse width & duty cycle should be considered as well) can cause localized overheating and voltage breakdown before heat has time to conduct away from the resistive element, even if the average power is not in excess.

#### 1.4 Excessive Average Power

Input power exceeding the rated average will cause permanent damage and failure. Operation must be limited to the nominal power.

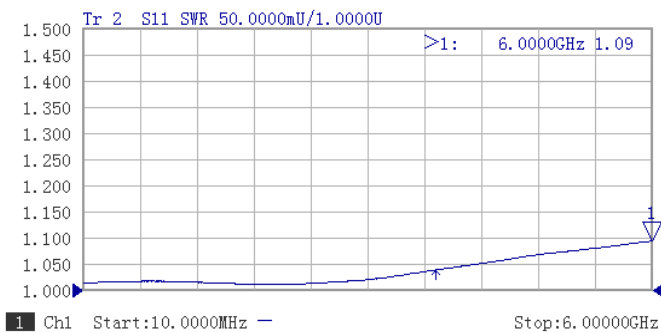
### 1.5 Input/Output Connection Reversal

In high-power attenuators, the internal resistor network is designed with a power-gradient distribution. Reversing the input and output ports forces low-power-rated resistors to handle excessive power, resulting in immediate or accelerated failure.

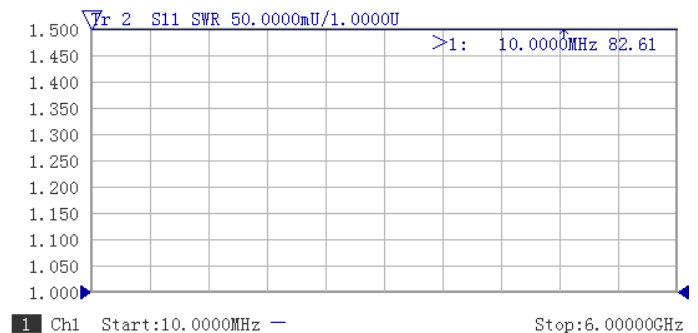
## 2. Failure Manifestations

### 2.1 Electrical Performance Anomalies

Degraded VSWR: Initial VSWR may appear normal, but after several minutes of operation, it deteriorates sharply.

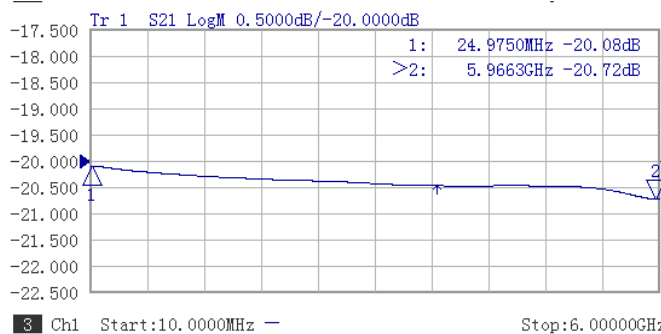


Initial VSWR

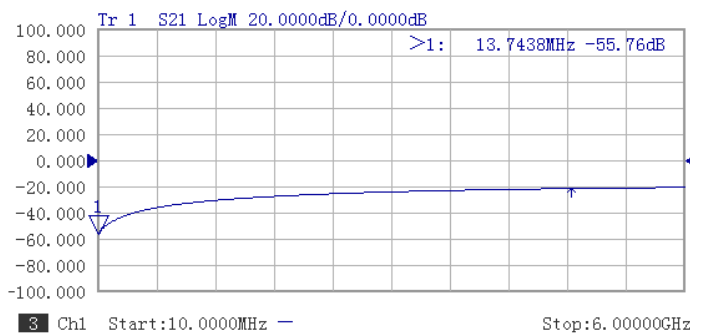


Degraded VSWR

Attenuation shift: Attenuation value shifts abruptly from its normal data, causing unstable output power and system malfunction.



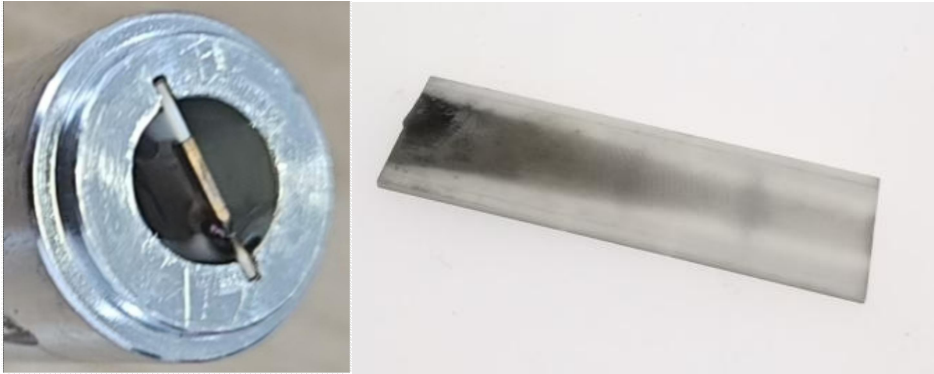
Initial Attenuation



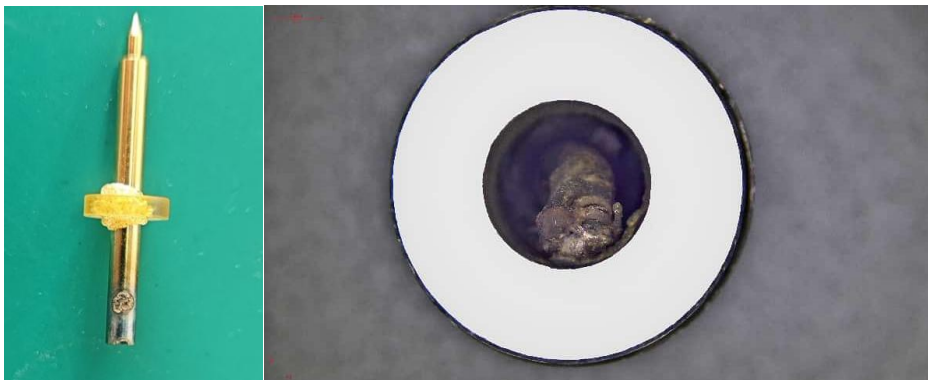
Degraded Attenuation

## 2.2 Physical Damage Indicators

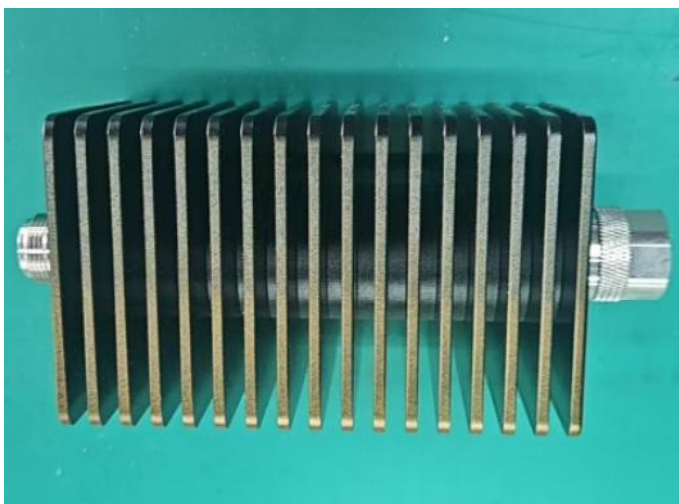
Burnt Resistor Elements: Localized cracks or burnout of the resistive film.



Connector Dielectric Damage: Carbonization of insulating materials due to excessive temperature.



Housing Discoloration: Heat sink discoloration under extreme thermal stress.



### 3. Preventive Measures to Avoid Attenuator Failure

- It is highly recommended to operate the attenuator at 50%–70% of the rated avg power if the operation time is continuously long over 15 minutes.
- For pulsed signals, verify both peak(including pulse width and duty cycle) and average power, ensuring sufficient safety margins.
- For conduction-cooled attenuator, ensure the mounting surface is flat, clean and in full contact with the housing.
- Equip with appropriately sized heat sinks and forced-air cooling when necessary.
- Maintain system impedance matching to minimize VSWR. Avoid use in environments with high signal reflection (e.g., mismatched antennas or open/shorted loads).
- For high-power testing, initiate with a low-level signal to allow the resistive element to reach thermal equilibrium gradually, avoiding high-power signal from cold-start.
- Always connect according to input/output markings.
- Apply proper torque to connectors to ensure reliable mechanical and electrical contact.
- Monitor and keep the case temperature under 85 °C.

### 4. The Importance of Case Temperature Monitoring

#### 4.1 Why Ambient Temperature Measurement Is Not Recommended

The term “ambient temperature” lacks a standardized definition. It may refer to:

- Air temperature near the component,
- Internal chassis air temperature,
- Laboratory bench temperature, or
- Inlet/outlet airflow temperature.

This variability introduces significant uncertainty into thermal design and power derating calculations.



In real-world systems, the local environment around the device is inevitably heated by the system's own operation, making it impossible to measure a truly "undisturbed" ambient temperature. Consequently, power ratings based on ambient temperature are often unreliable.

Since permanent failure in coaxial attenuators is predominantly induced by excessive internal temperatures resulting from inadequate heat dissipation, continuous monitoring of the attenuator's case temperature is essential to ensure operational safety.

## 4.2 Advantages of Case Temperature Monitoring

4.2.1 Case temperature integrates the net effect of all thermal factors—including airflow, mounting contact quality and installation direction, and system congestion etc., providing a real-time assessment of actual heat dissipation capability.

4.2.2 Users can quickly assess safety by touch or non-contact measurement. The measurement location is recommended in the center of the attenuator housing, and the recommended tools can be Infrared (IR) thermometer (set emissivity to 0.85–0.90 for black-anodized heat sink) or use thermocouple which has higher accuracy than thermometer.

### Suggested Safety Thresholds for Case Temperature:

Normal range: < 70°C (suitable for continuous operation)

Warning range: 85°C-90°C (Action needed: cooling or reduce input power)

Critical range: > 100°C (immediately enhance cooling or reduce power)

## 5. Our Technical Countermeasures

### 5.1 Heat Sink Design

The heat sink geometry in our convection-cooled attenuators, including its overall size and fin spacing, is meticulously engineered to achieve optimal thermal resistance.

### 5.2 Advanced Material Selection

Our attenuators rated >5W utilize high-thermal-conductivity substrates (Beryllium Oxide, BeO). The resistive film and ceramic substrate are engineered with matched coefficients of thermal expansion (CTE), minimizing thermomechanical stress during thermal cycling.



### 5.3 Enhanced Quality Control

All units (>100W average) are subjected to pre-shipment power test till case temperature exceeds 85°C . This test identifies potential early-life failures due to manufacturing or material issues before shipment.

#### **Conclusion**

Based on our extensive field experience and continuous engineering refinement, we have established thermal management as the cornerstone of reliability in high-power RF coaxial fixed attenuators. By integrating thoughtful model selection, rigorous installation practices, and real-time thermal surveillance, users can greatly enhance the service life and operational reliability of their RF systems.

P.S. Test data for RF ONE's 6GHz 200W N type Attenuator.



<b>Power Test on 6GHz 200W N type Attenuator RFH0630NA200</b> Lab room temperature is air-conditioned around 20 °C			
Time	Input RF Power (W)	Case Temp °C	Remarks
11:25	200	20	Start
11:27	200	42	
11:30	200	57	
11:32	200	62	
11:35	200	66	
11:40	200	74	
11:45	200	78	
11:50	200	85	
11:55	200	87	
12:00	200	90	
12:05	200	90	
12:05	200	90	Begin fan cooling
12:07	200	82	Fan cooling continued
12:10	200	67	Fan cooling continued
12:15	200	62	Fan cooling continued, case temp stabilized

Under rated 200W CW power with adequate forced-air cooling, the case temperature stabilizes at ~62°C, well within the safe operating range. When case temperature >90 °C and no fan cooling is applied, it does not mean the attenuator will fail soon. Keeping the case temperature under 85°C can significantly enhance the attenuator service life and the optimal RF performance.