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Rated Power and VSWR Improvement of Termination Resistor with Integrated Matching Network

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Outline

- ❑ *Motivation*
- ❑ *Review of RF/Microwave termination resistor*
- ❑ *Applied techniques to enhance power handling capability of RF termination resistor*
- ❑ *Result of power handling capability enhancement with test data*
- ❑ *Product improvement to prevent failure due to thermal fatigue*
- ❑ *VSWR improvement technique with impedance matching network*
- ❑ *High Z / Low Z and DGS technique and its effectiveness*
- ❑ *Test result of Manufactured products*
- ❑ *Summary and conclusion*
- ❑ *Acknowledgement and Future work*

Motivation

- ❑ Wireless telecom., broadcast and radar industry rely on high power radio wave transmission to reach subscribers or measure environment.
- ❑ As the wireless revolution extends, components need to work with higher freq., elevated operating power, smaller in size and improved performance.
- ❑ RF/Microwave termination resistors need to have impedance matching capability along with higher power handling capability.
- ❑ Research was done to design and manufacture RF termination resistor with enhance power handling capability along with excellent Return Loss characteristics for higher frequency.

Review: RF/Microwave Termination Resistor

- ❑ Typical RF Termination Resistor
 - ❑ 50 Ω Termination Resistor at the end of the RF resistor
 - ❑ Impedance matching network at the beginning of the RF resistor
 - ❑ Ground plane at the bottom of the RF resistor
- ❑ Necessary Improvement
 - ❑ 50 Ω Resistor Parameters
 - ❑ Enhance power handling capability
 - ❑ Size reduction, Tighter tolerance, Low TCR value
 - ❑ Impedance Matching Network Parameters
 - ❑ Improve Return Loss Characteristics
 - ❑ Work with higher frequency

Enhance Power Handling Capability

- ❑ Higher applied power generate higher temperature
- ❑ Thermal Management
 - ❑ Excessive heat can cause irreversible damage to resistor product
 - ❑ Must reduce excess heat from resistor
 - ❑ Can not let the generated heat stay in the resistive material for prolonged period of time
- ❑ Heat Dispersion from resistor product
 - ❑ Gradual radiation to air through surface material
 - ❑ Conduction through the substrate then to the circuit board, ultimately by convection from PCB
 - ❑ Through pattern then through land pad termination to PCB then convection from PCB

Enhance Power Handling Capability

Uniform Heat Distribution

- Resistive area as big as possible
- Eliminated one single hot area
- Peak surface temperature is uniformly distributed
- Power specification does not need to depend on one single hot spot

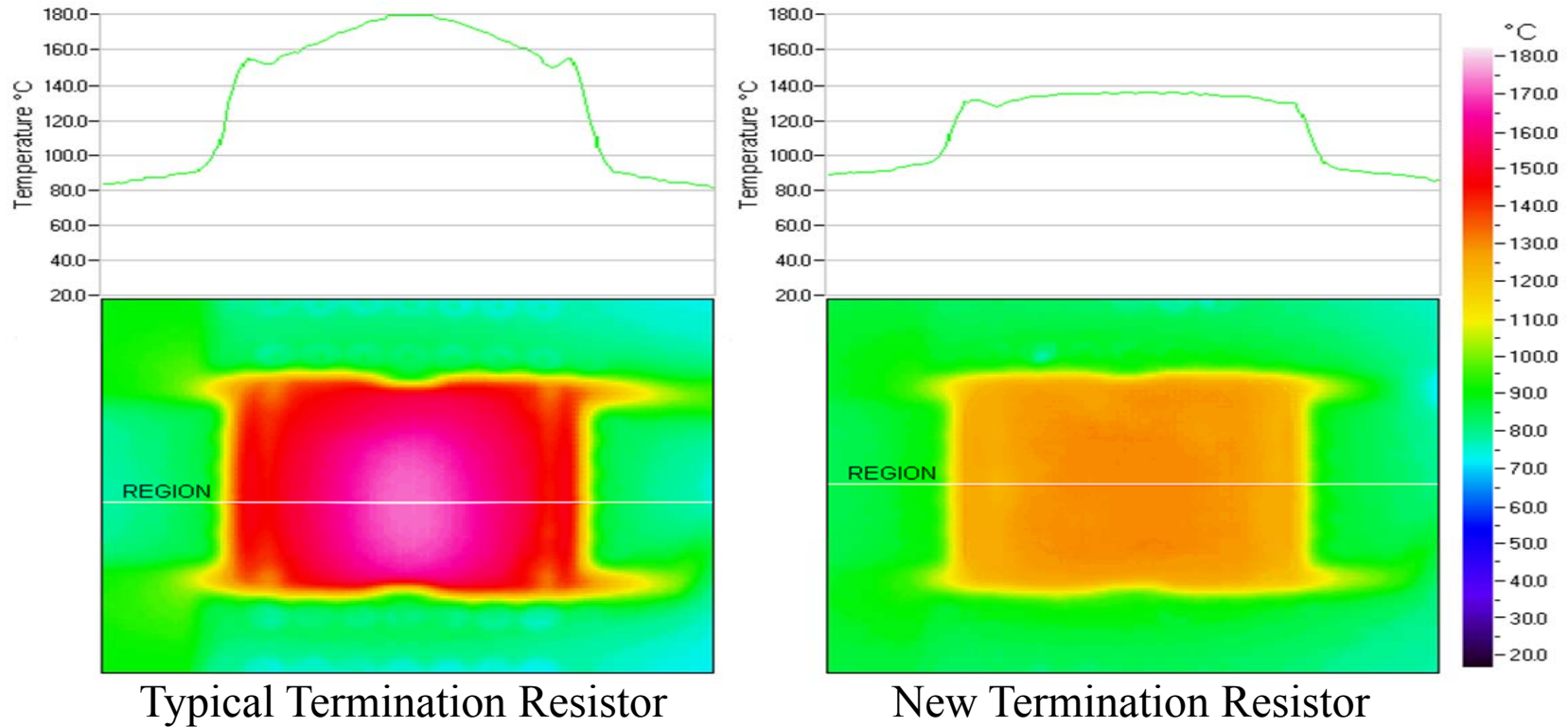
Improve Current Density

- Maximum current density – Maximum tolerated current per unit of cross sectional area
- Used NiCr as resistive material; NiCr has very high current density limit
- Bigger resistive area also improves current density
- Reduced electro migration effect

Enhance Power Handling Capability

- ❑ Improve Heat transfer rate through Footprint
 - ❑ Lowered thermal resistance interface from resistor to circuit board
 - ❑ NiCr is deposited directly to substrate, resulting less thermal resistance between material and substrate
 - ❑ Maximized termination electrode's size
 - ❑ Used high purity, high thermal conductivity material for terminal footprint
 - ❑ Special design is considered to ensure balance distribution of generated heat
 - ❑ Improved heat transfer rate through the termination material
 - ❑ Used AlN as substrate for better thermal properties

Thermal Profile Comparison and Result



- ❑ Typical Res. peak surface temp = 180°C; New Res. peak surface temp = 135°C
- ❑ PCB temp with typical Res. = 90°C; PCB temp with New Res. = 100°C
- ❑ Component size = 2525, Power = 100 Watt, PCB = FR 4

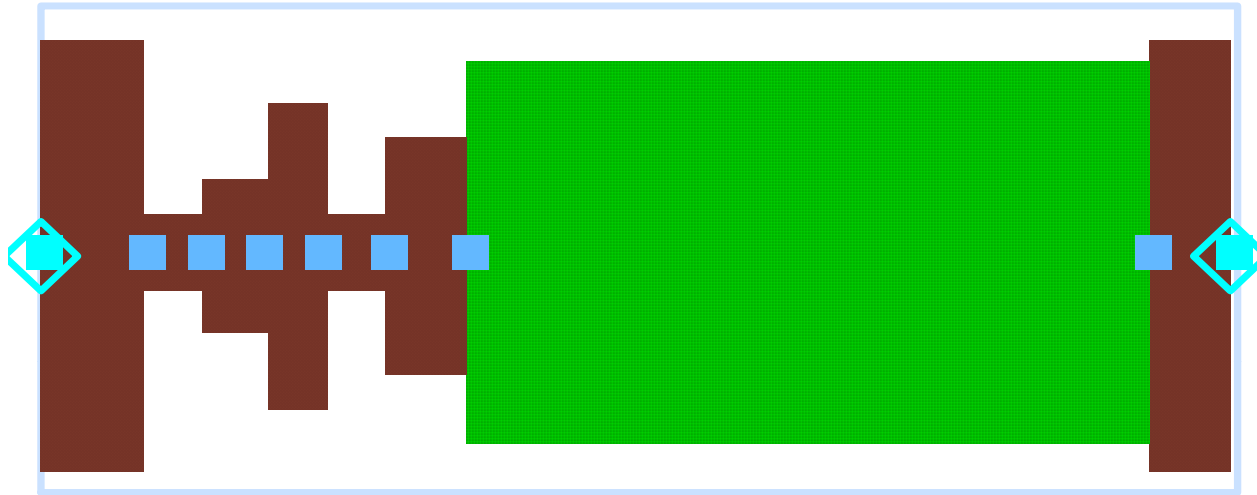
Reduce Thermal Fatigue

- ❑ Thermal Fatigue
 - ❑ High temperature can exceed melting point of mounting solder
 - ❑ It can potentially create crack in the solder joint
 - ❑ Causes irreversible damage to resistor, Changes resistor value
 - ❑ Decreasing resistor reliability, Potential damage to PCB
 - ❑ Depending on the applied power, temperature rise and fall
 - ❑ PCB and Resistor expands and contracts
 - ❑ Different expansion and contraction rate of both material can make crack in solder joint
- ❑ Reduced Thermal Fatigue
 - ❑ Used termination material with similar CTE value as PCB
 - ❑ Removed heat as quickly as possible from Resistor

Improve Return Loss Characteristics

- ❑ Return loss characteristics is controlled with Z matching network
- ❑ Typically it is done by serpentine or L- shape microstrip line
 - ❑ Occupies more space on the component surface
- ❑ We used High Z/Low Z impedance matching network
- ❑ Used Deformed Ground Structure (DGS) technique
 - ❑ Reduced area for impedance matching network

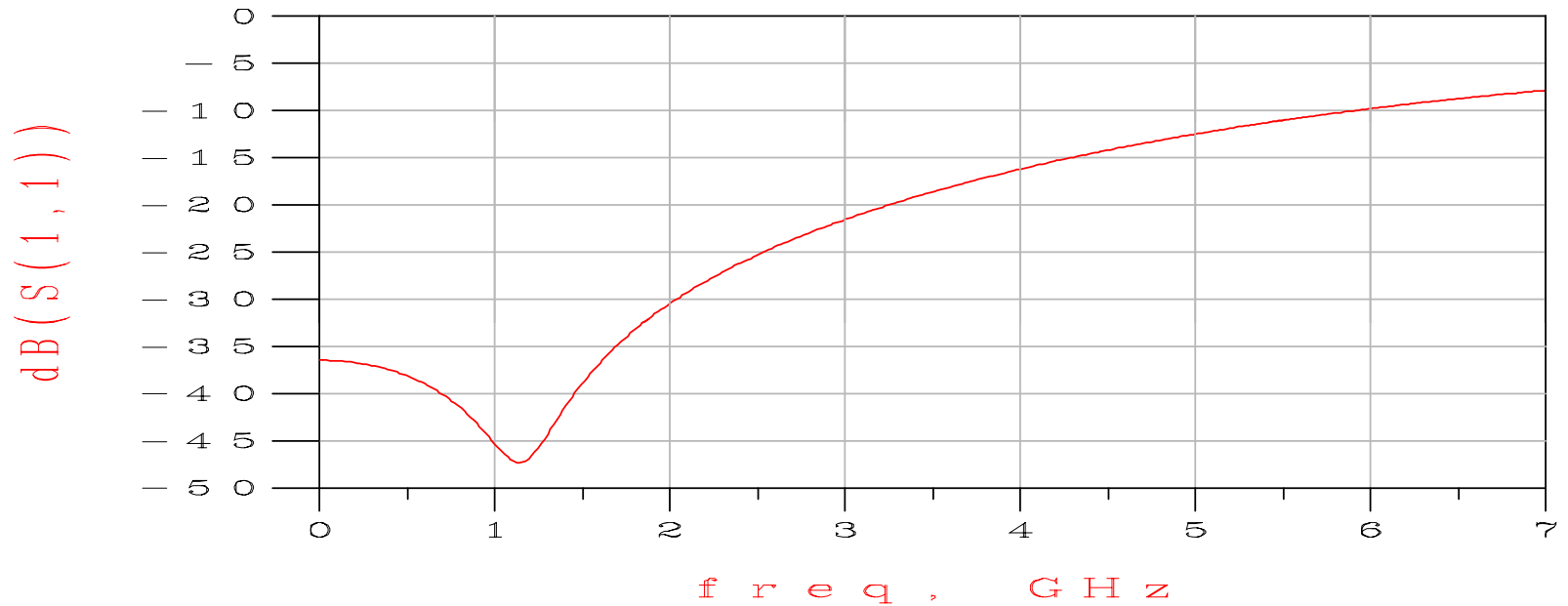
20W Termination Resistor Design



Resistor design Layout simulation work

- High Z / Low Z Impedance matching network
- 50 Ω resistor at the end of the component
- Power handling capability = 25 Watt
- Substrate = AlN, Thermal conductivity = 170 – 180 W/m $^{\circ}$ C
- Resistive material = NiCr

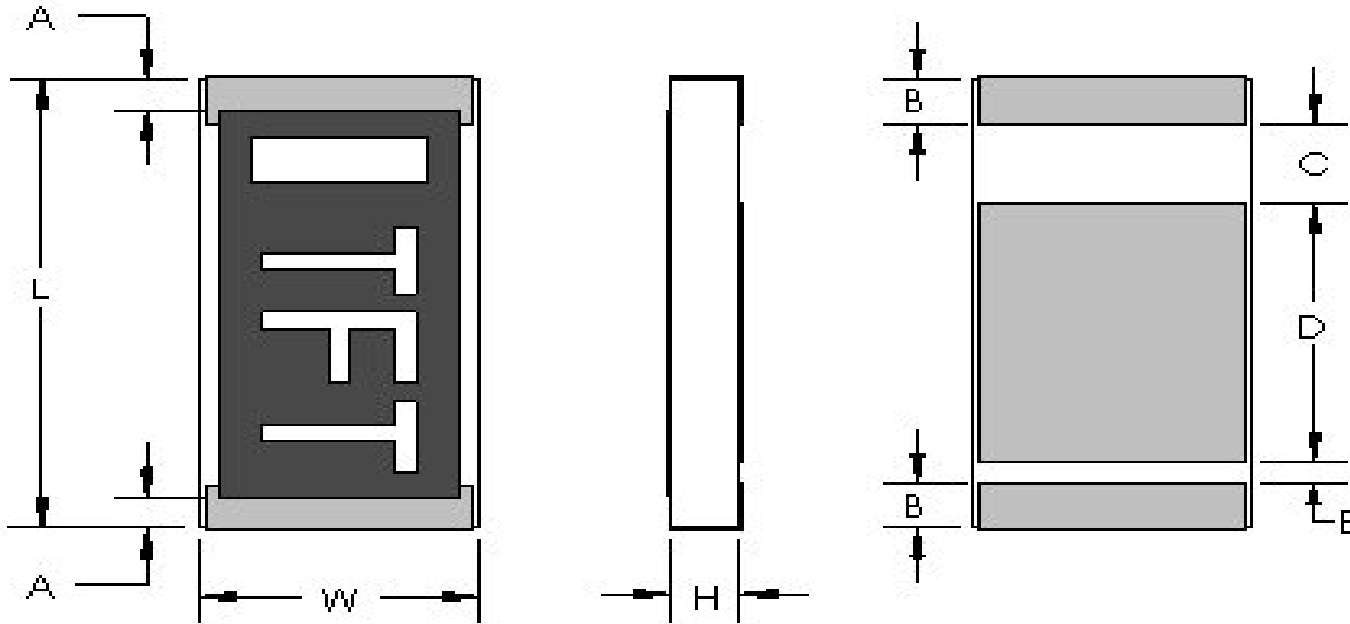
20W Termination Resistor Design



Resistor design Simulation result

- Return loss is down to -22 dB at 3.0 GHz, and - 16 dB at 4. 0 GHz frequency

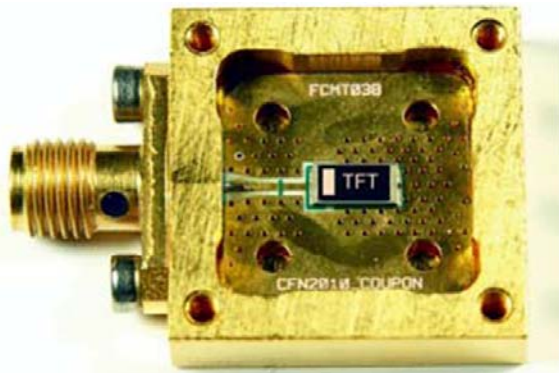
20W Termination Resistor Design



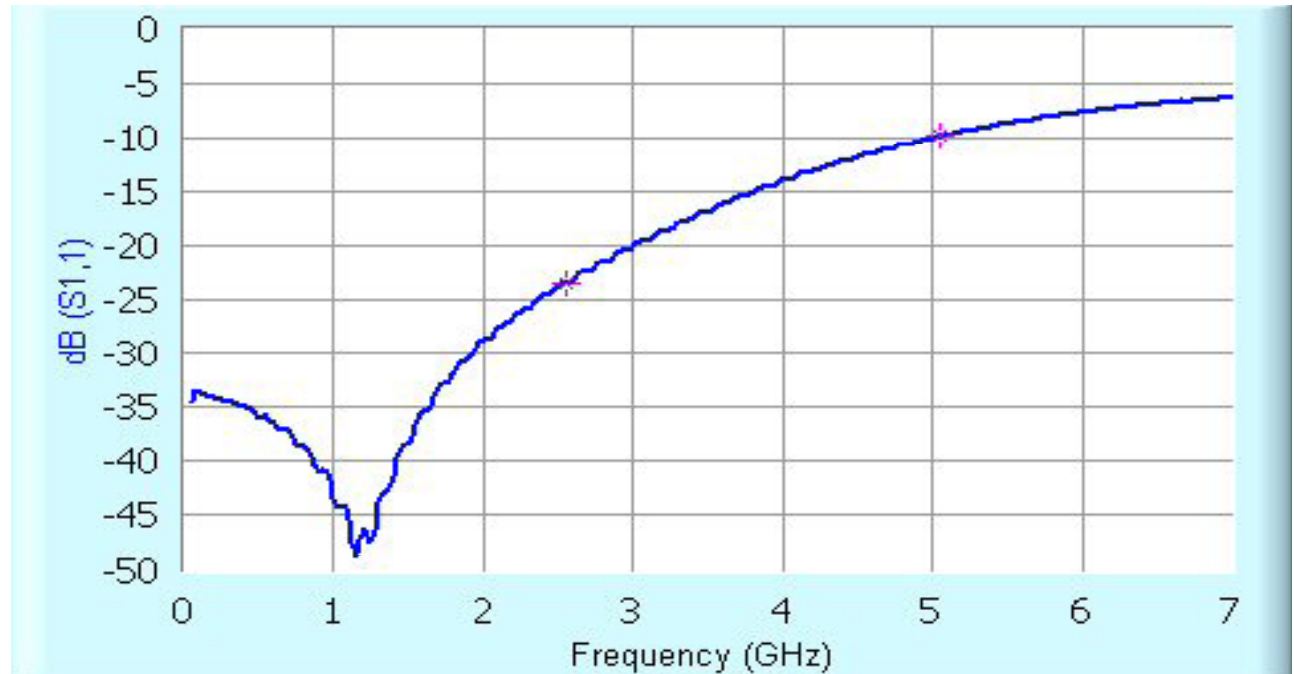
Resistor design Mechanical drawing with DGS

- Ground is not continuous to obtain better impedance match
- Size = 2010

20W Termination Resistor R.L. Result



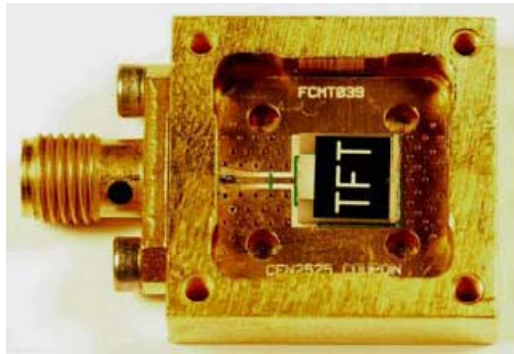
20 W Resistor in Eval board



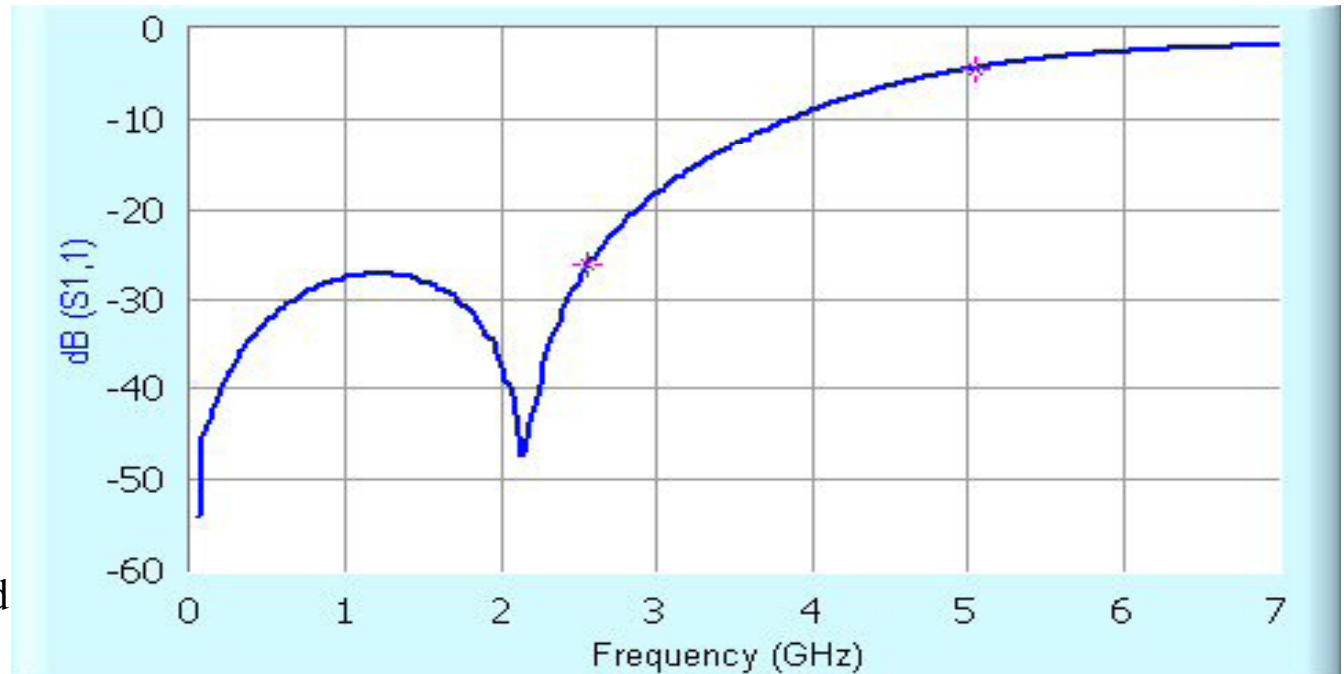
Return loss test result

- ❑ Eval board is Rogers 4350B, 10 mil thick PCB
- ❑ At 3.0 GHz freq. Return loss = -20 dB, VSWR = 1.16:1
- ❑ At 4.0 GHz freq. Return loss = -14 dB, VSWR = 1.41:1

100W Termination Resistor R.L. Result



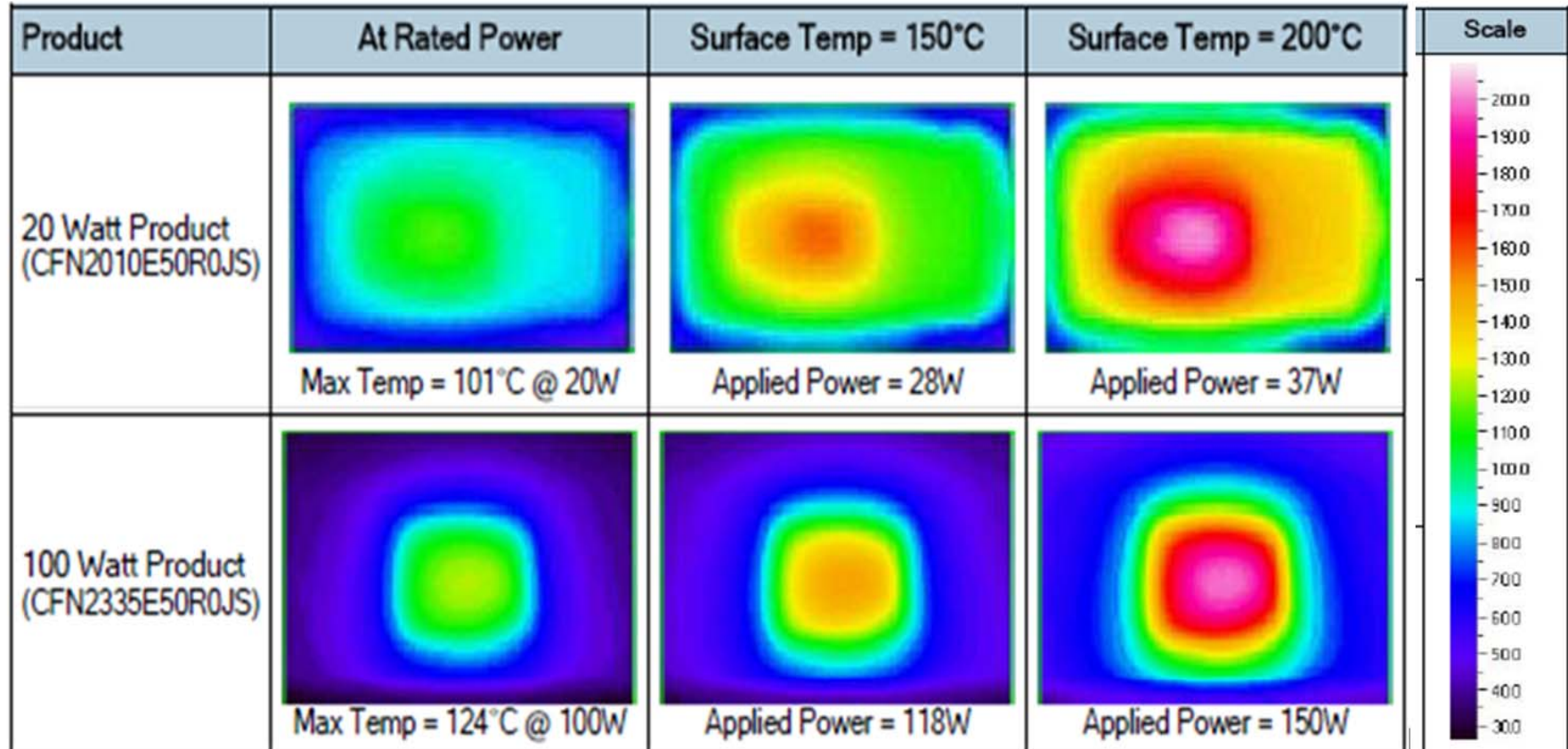
100 W Resistor in Eval board



Return loss test result

- ❑ Eval board is Rogers 4350B, 10 mil thick PCB
- ❑ At 3.0 GHz freq. Return loss = -20 dB, VSWR = 1.16:1
- ❑ At 4.0 GHz freq. Return loss = -9 dB, VSWR = 1.95:1

Power Handling Capability Result



Thermal profile of 20 W and 100 W termination resistor

- ❑ These resistors can handle 1.5 times the rated power
- ❑ TCR = 25 ppm, Tolerance = 1%

Summary and Conclusion

- ❑ Research was done to enhance power handling capability of RF termination resistor
- ❑ Effective thermal management reduced peak surface temperature
- ❑ Using termination material with similar CTE of PCB, product was improved to prevent reliability failure due to thermal fatigue
- ❑ Improved Return Loss characteristics with integrated impedance matching network with DGS technique
- ❑ High Z/Low Z micro strip line used to reduce matching network size
- ❑ Design and manufactured result was illustrated
- ❑ Resistor can tolerate 1.5 times of rated power with good VSWR result

Acknowledgement and Future Work

- Future Work
 - Future work will be done on other series of resistors with high power handling capability
 - Return Loss Characteristics can be improved further for higher frequency range
 - Improve component tolerance value and TCR value
 - Reduce size
- Acknowledgement
 - We would like to acknowledge Yokohama Denshi Seiko Co. for sharing valuable knowledge and resource

**Thank you for your time
and attention**