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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

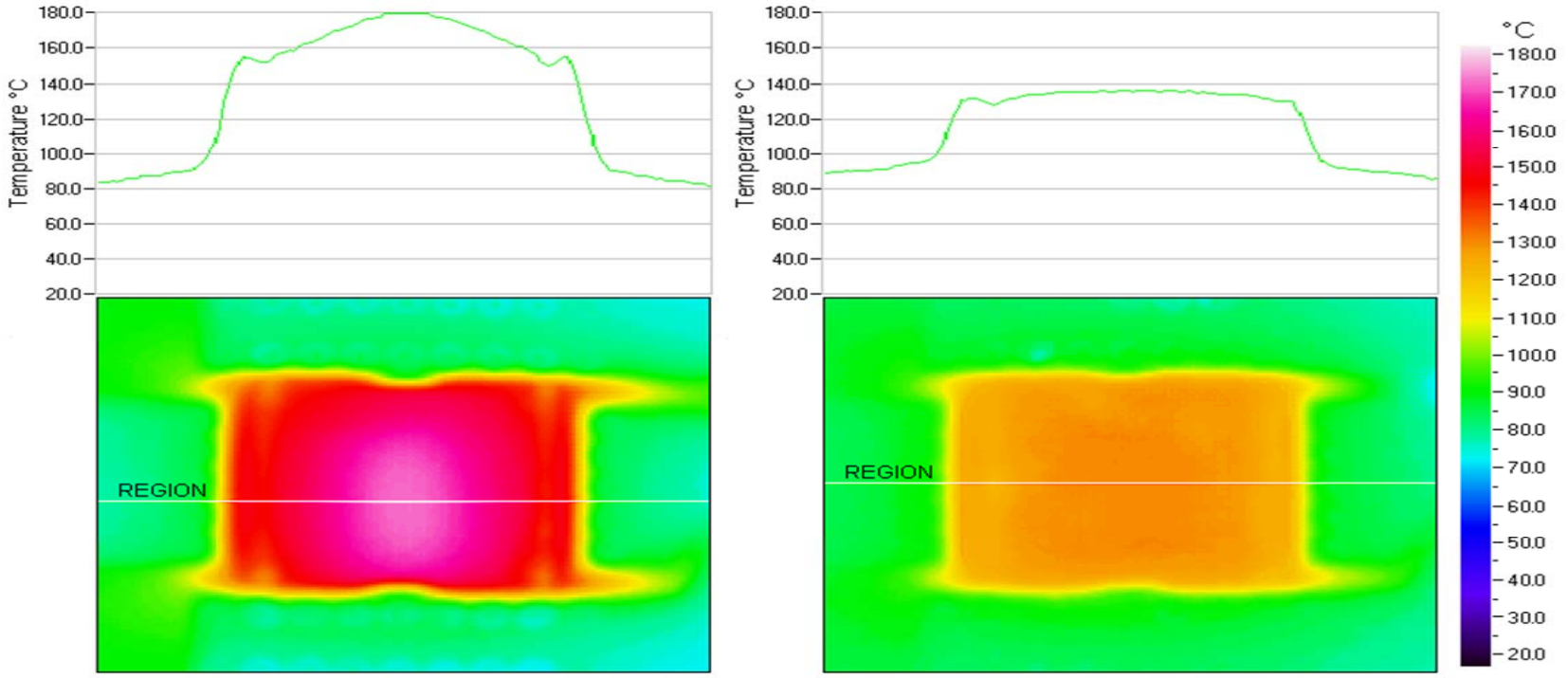
Enhance Power Handling Capability

- 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 Termination Resistor

New Termination Resistor

- 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

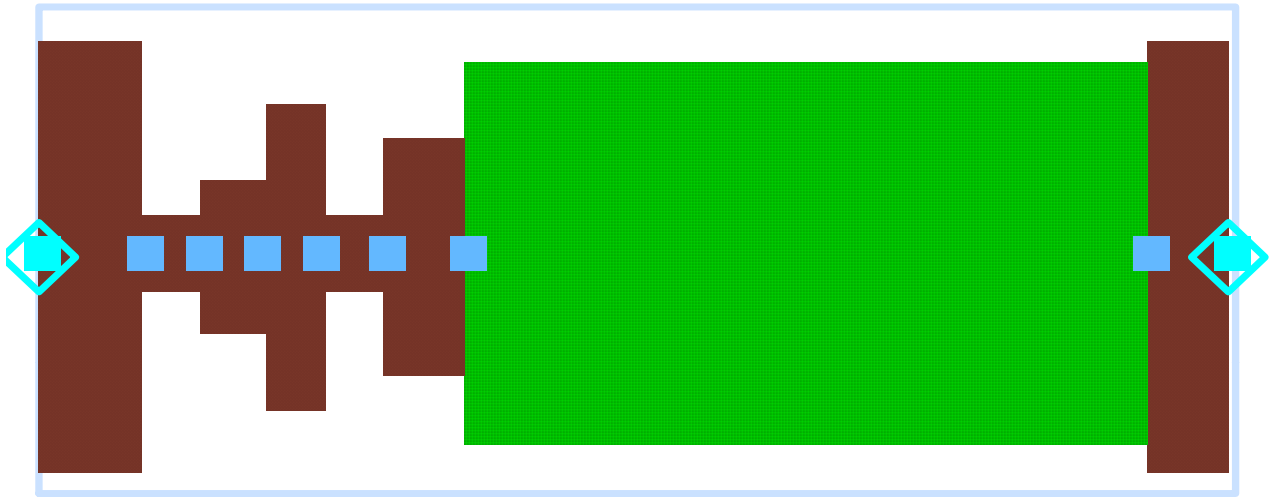
Reduce Thermal Fatigue

- 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

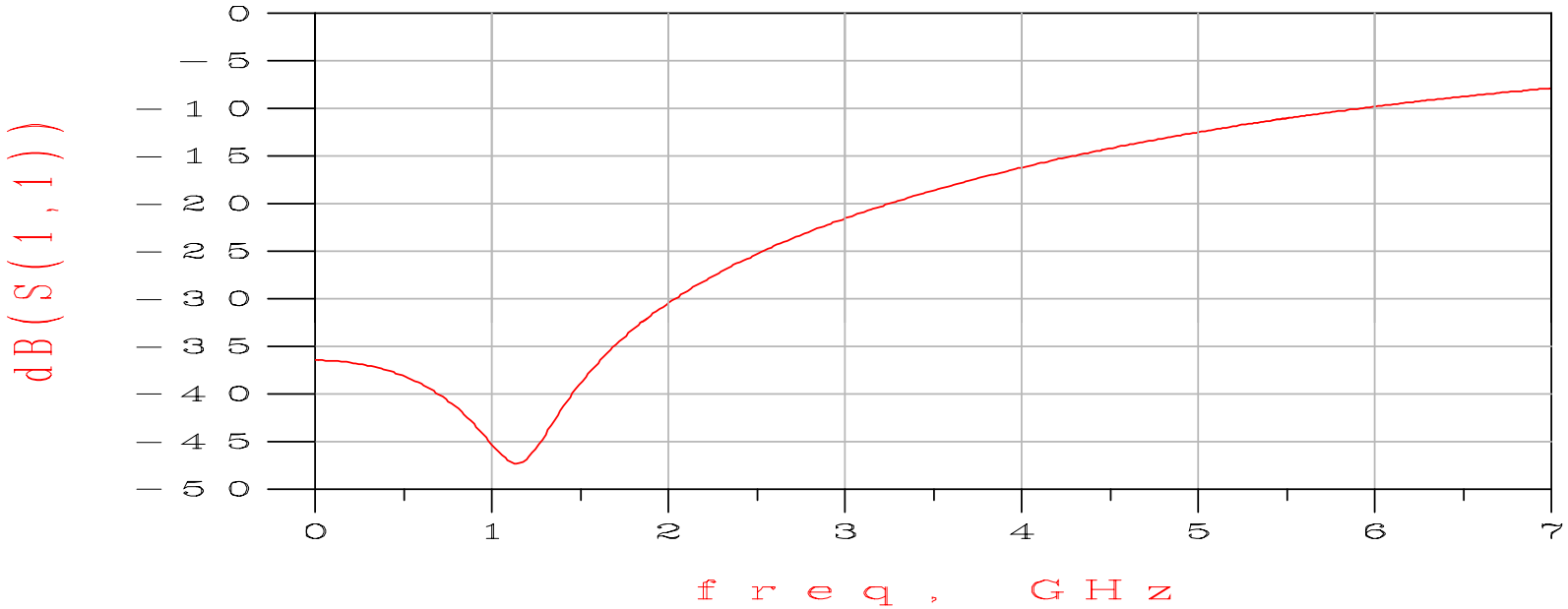
20W Termination Resistor Design



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˚C
- Resistive material = NiCr

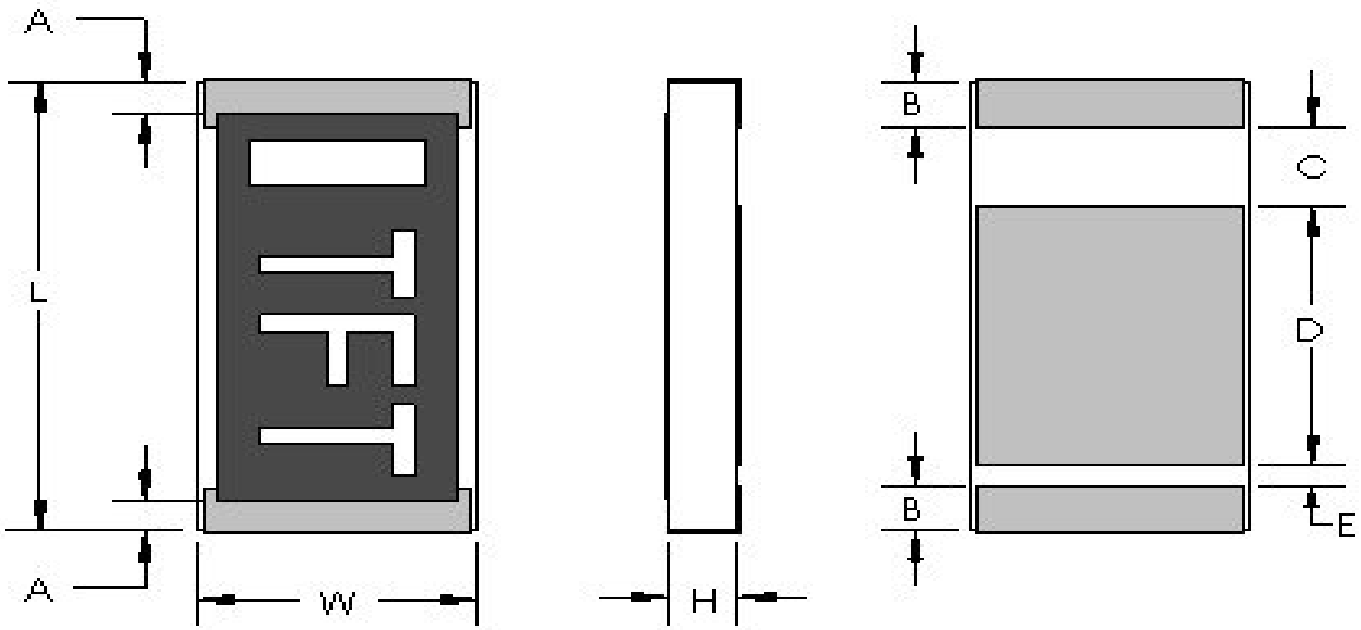
20W Termination Resistor Design



Resistor design Simulation result

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

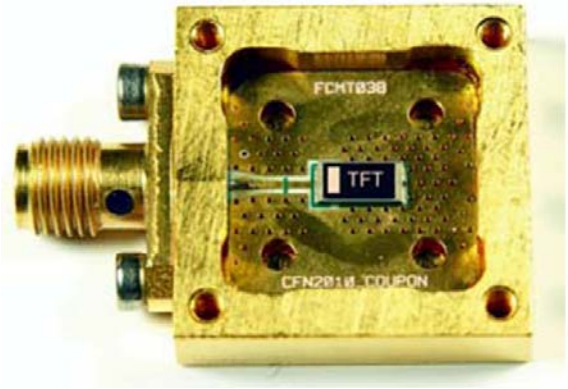
20W Termination Resistor Design



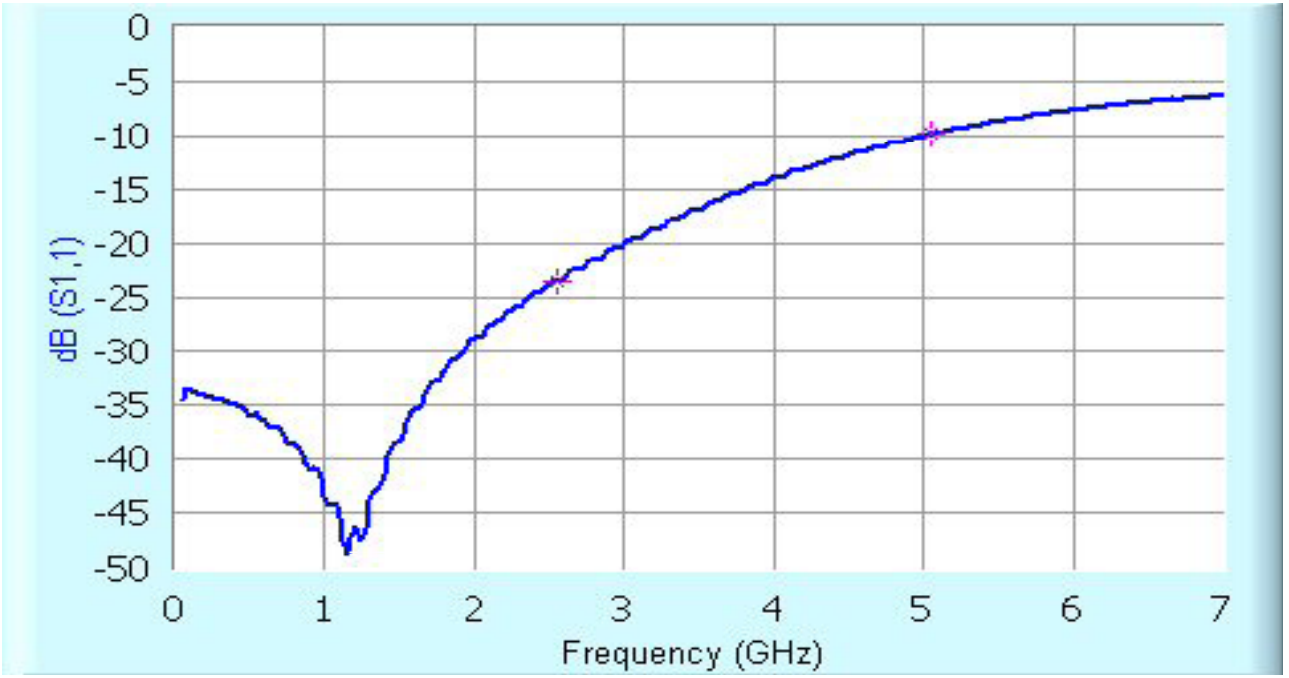
Resistor design Mechanical drawing with DGS

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

20W Termination Resistor R.L. Result



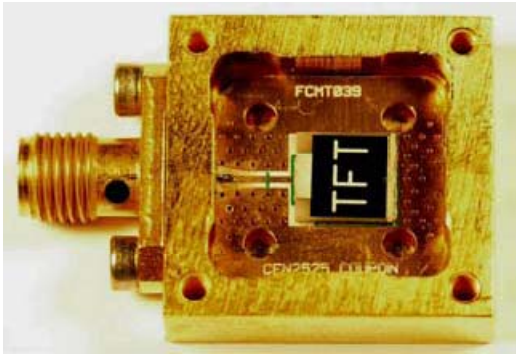
20 W Resistor in Eval board



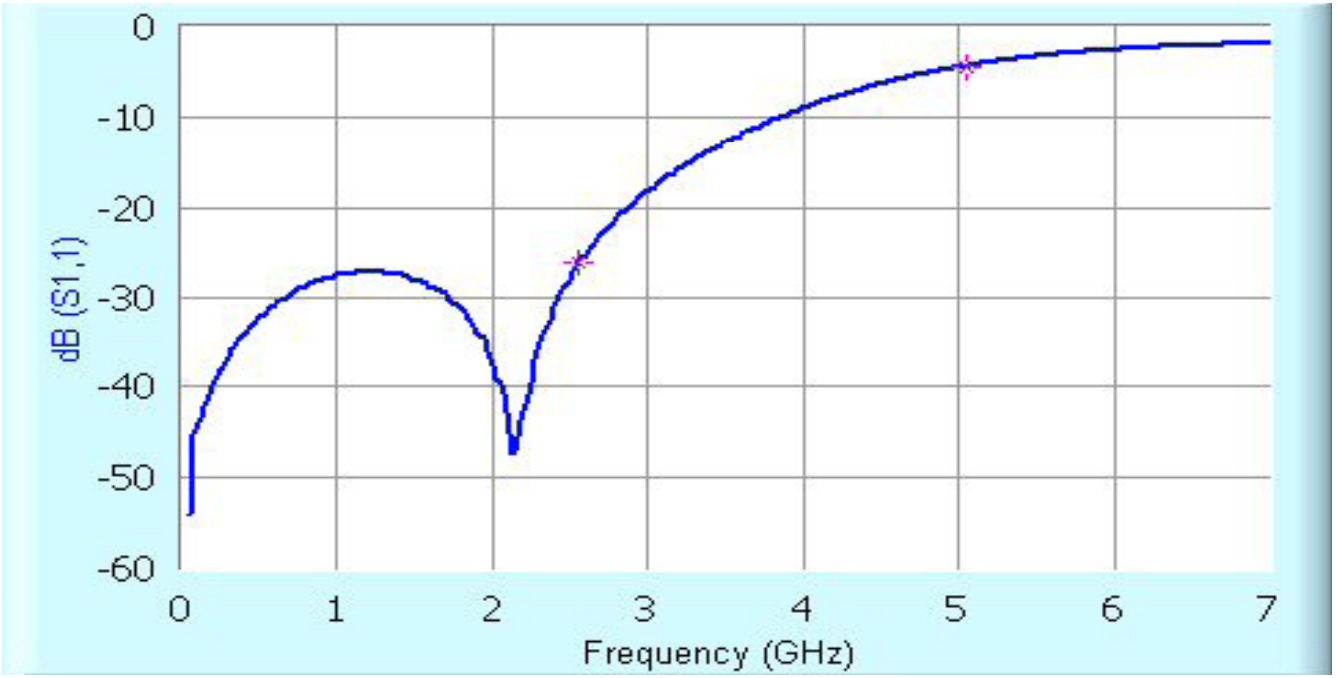
Return loss test result

- 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



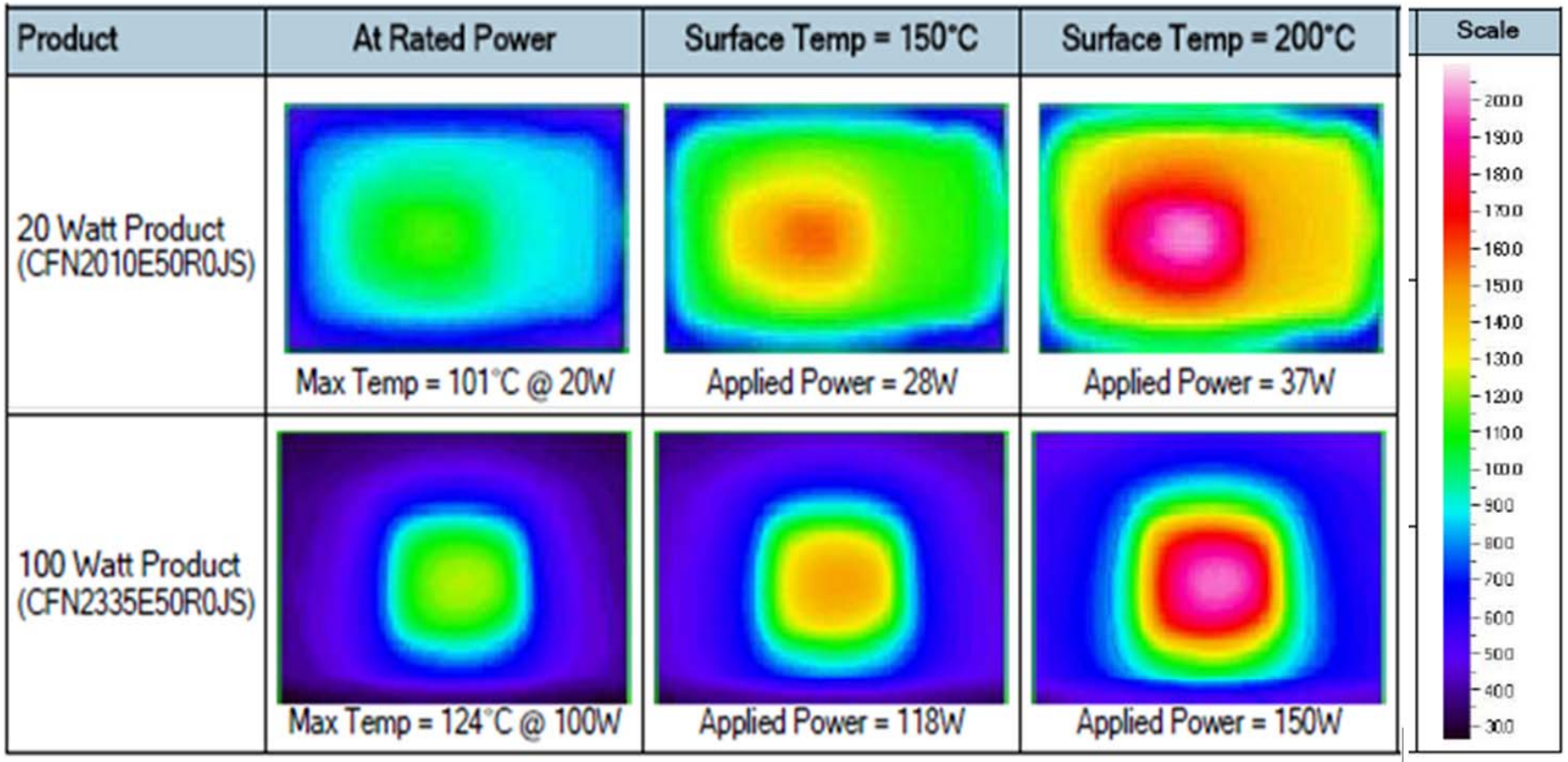
100 W Resistor in Eval board



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