Integrated Thin-Film Resistor Materials for High-Frequency Applications

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Agenda

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- Why AESA Radar Performance is Getting Harder
- Hidden Cost of Discrete RF Resistors

Embedded Resistors: From Lumped Components to Planar RF Elements

- Electrical Comparison
- Reliability Comparison

Resistor Tolerance

- Design Checklist
- Wilkinson Power Divider Test Plan
- Material Options
- Summary
- Q&A

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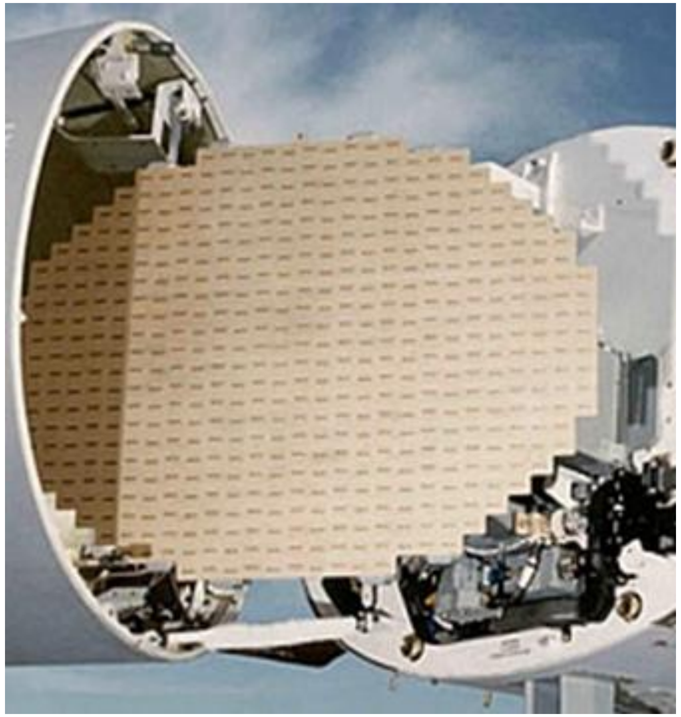
Why AESA Radar Performance Is Getting Harder

- Higher frequencies (X → Ka → mmWave)
- Larger arrays, tighter phase budgets
- Increased channel density
- Calibration stability challenges



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The Hidden Cost of Discrete RF Resistors

- Parasitic inductance and capacitance
- Via transitions in RF paths
- Solder joint variability
- Assembly-driven mismatch

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Embedded Resistors:
From Lumped Components to Planar RF Elements

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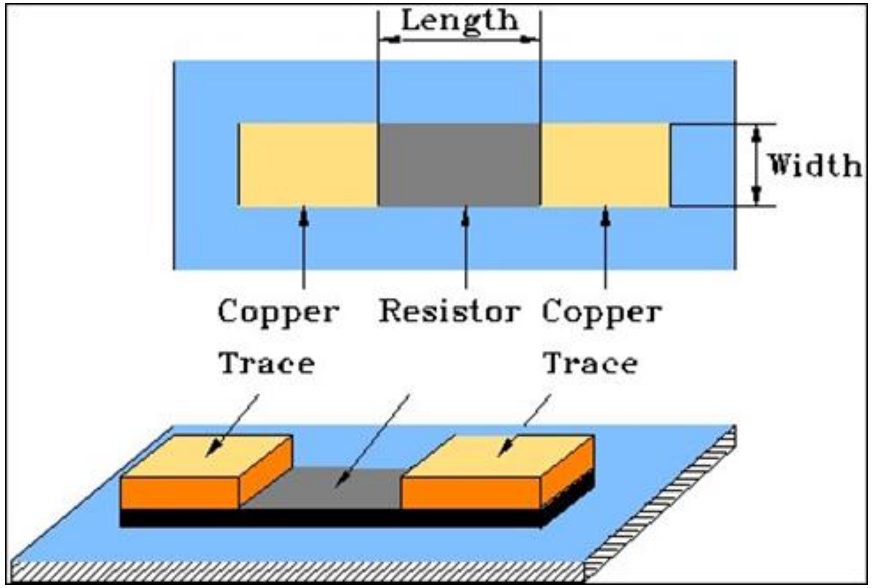
- Planar, lithographically defined
- No solder joints
- No vias in signal path
- Geometry-controlled resistance



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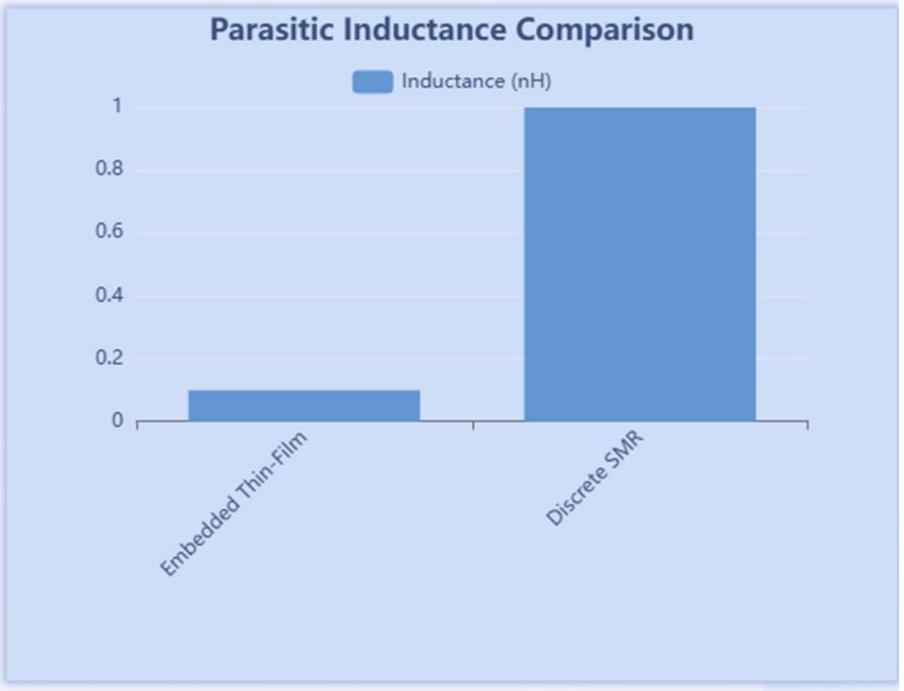
Performance Comparison

- Embedded thin-film resistors outperform discrete SMRs in critical RF metrics
- Near-zero parasitic inductance **(< 0.1 nH vs 0.5–1.0 nH**)
- Lower insertion loss **(< 0.05 dB @ 40 GHz vs 0.1–0.2 dB**)
- Improved phase consistency **(±0.5° vs ±5–10°)**
- No surface board area required (embedded structure)
- Eliminates solder fatigue risk
- Excellent thermal stability

Parasitic Inductance Reduction

- Embedded resistors reduce parasitic inductance by up to **90%**
- Typical values:
- Embedded: **< 0.1 nH**
- Discrete SMR**: ~1.0 nH**
- Critical for signal integrity above 40 GHz
- Enables improved high-frequency consistency
- Reduces impedance distortion in RF signal paths



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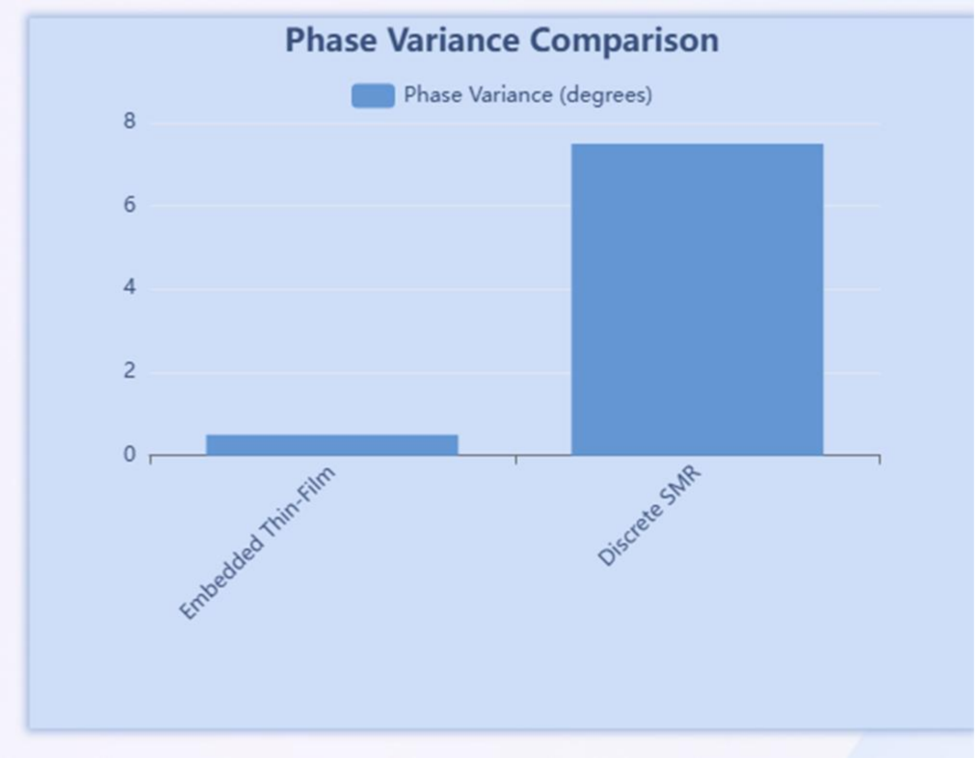
Phase Consistency Excellence

- Up to 15× improvement in phase consistency vs discrete SMRs
- Embedded: **±0.5°** typical variance
- Discrete SMR**: ±7.5°** average variance
- Reduces need for post-fabrication calibration
- Improves uniformity across array channels
- Enhances beamforming accuracy



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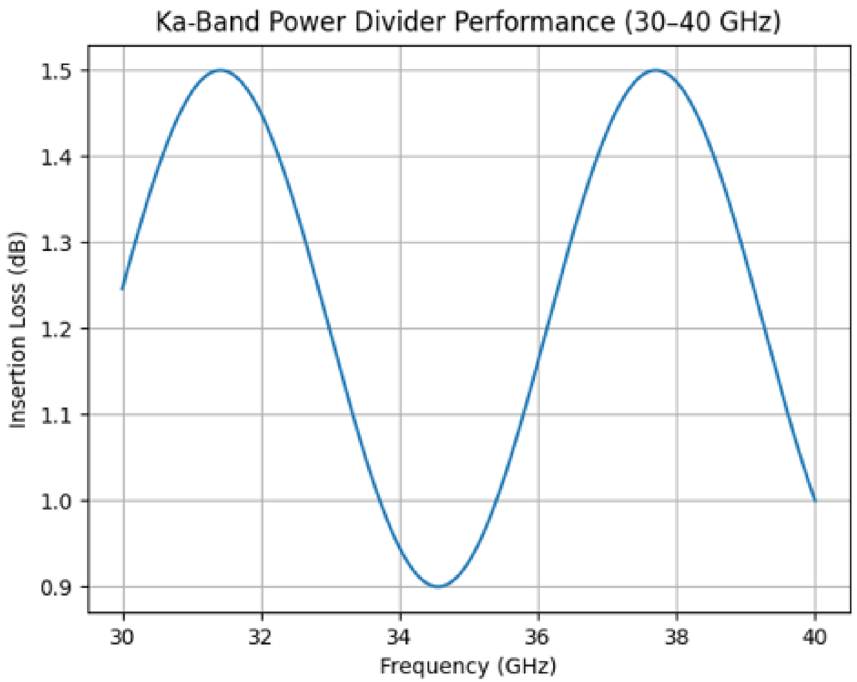
Ka-Band Power Divider Performance (30-38 GHz)

- 3-way power divider demonstration
- **23.5%** operational bandwidth
- **< 2 dB** transmission loss
- **±0.55 dB** amplitude balance
- Demonstrates low-loss embedded resistor performance
- Validates suitability for Ka-band radar applications



Insertion Loss Advantage at 40 GHz

- 4× reduction in insertion loss vs discrete SMRs
- Embedded: **< 0.05 dB @ 40 GHz**
- Discrete: **~0.2 dB @ 40 GHz**
- Improves system-level RF efficiency
- Extends operational range
- Reduces RF power consumption

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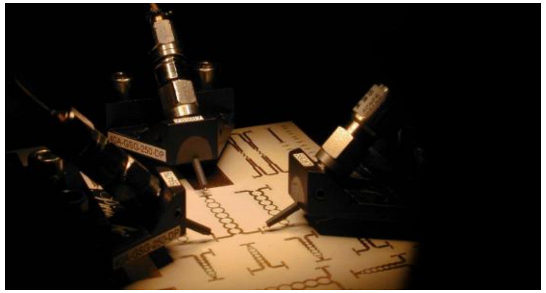
Application Specific Benefits

Phased-array transceivers (26–40 GHz)

- Uniform gain and phase
- Reduced mismatch

Wilkinson power dividers (2–40 GHz)

- High isolation
- Minimal footprint



Beamforming networks (~28 GHz)

- Compact, low-loss integration

Aerospace & defense modules (X / Ka-band)

- Lightweight, high-reliability builds

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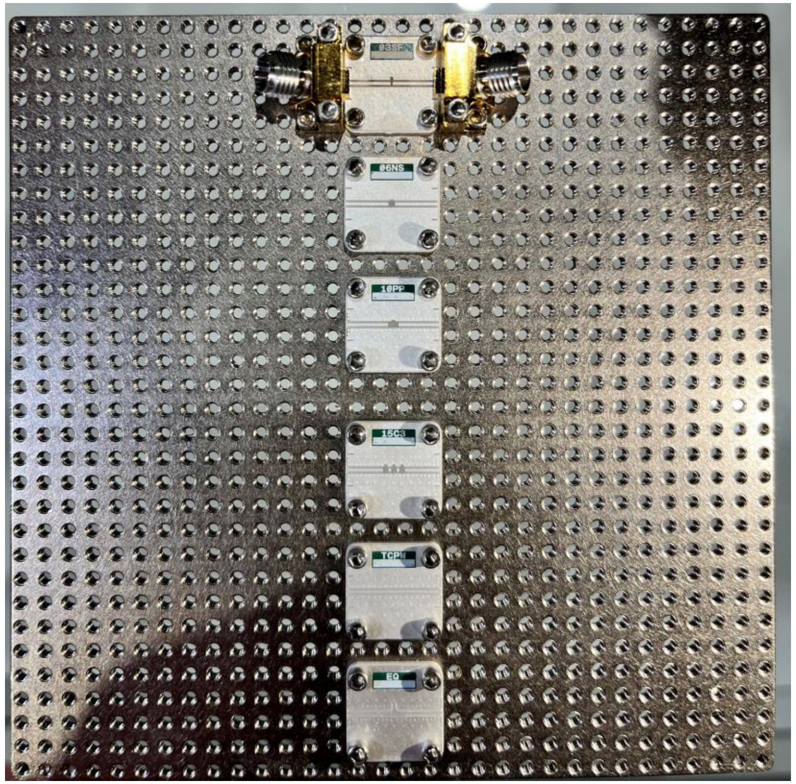
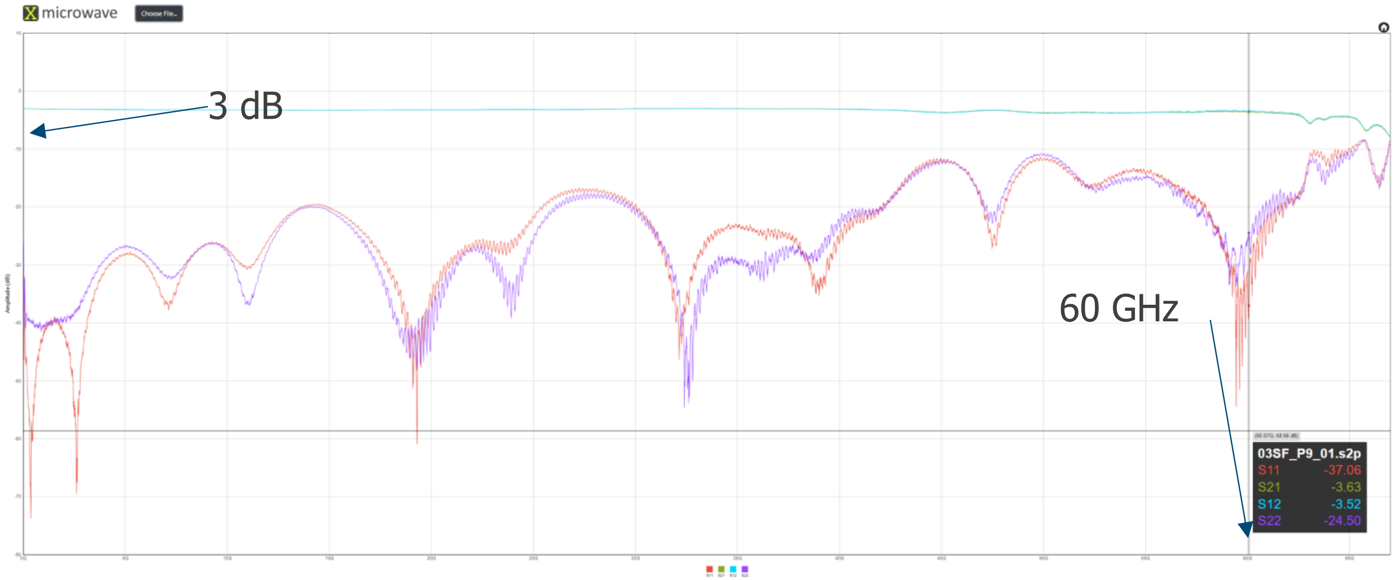
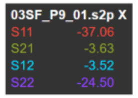
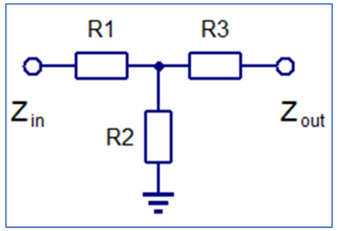
Measured RF Performance (Example: Attenuator)

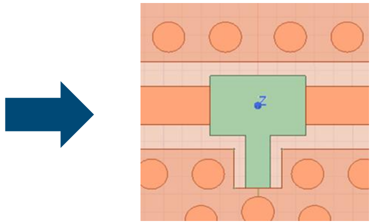
- Attenuator utilized a 3-resistor design (2 in series and 1 to ground)
- Designed for 3 dB up to 60 GHz
- Simulated and actual performance in agreement with excellent results











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Reliability for Mission-Critical Radar

- No solder fatigue
- No vibration-induced failures
- Stable over temperature cycling
  - Resistance Temperature Coefficient <110 ppm/^{o}C (-55 to 125 ^{o}C)
  - Tested for thousands of cycles

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Additional Benefits

- Space efficiency
  - Frees 100% of surface board area
  - Eliminates 2–10 mm² per resistor
- Thermal stability
  - Superior performance vs surface-mount resistors
- Signal integrity
  - Lower insertion loss
  - Improved phase consistency
- Cost efficiency
  - Reduces secondary placement and reflow steps
- Scalability
  - Suitable for prototyping and mass production
- Weight reduction
  - Ideal for aerospace applications

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What Drives Thin-Film Resistor Tolerance?

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Resistance Equation

- Resistor value = sheet resistivity x ratio of element length to width
  - $R = R_s \times (L/W)$
  - R_s tolerance of ±5-8%

Sources of Variation

- Lithography-controlled dimensions
- Geometry tolerance dominates
- Smaller resistors are expected to have higher resistor tolerance
- PCB processing can add +10-15%

•Typical Overall Tolerance

- ±15–20%
- Laser trimming rarely required

For RF applications, performance variation is dominated by geometry and parasitics, not nominal resistance tolerance.

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When NOT to Use Embedded Resistors

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- Very high-power dissipation in a small area
- Late-stage value trimming required
- Applications requiring post-assembly tuning flexibility
- Low-frequency, cost-only designs

Note: Maximum Power Handling Calculators are available

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Design Checklist for Engineers

1) Identify resistors in RF signal paths
2) Replace vias + chips with planar elements
3) Simulate with EM solver
4) Validate geometry tolerance
5) Include calibration impact

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Wilkinson Power Divider - Test Plan

- Most information is generated by customers
- Not all information is shared
- Decided to build our own test vehicles
  - Two different copper profiles
  - Two different materials (Thermoset and Thermoplastic)
  - Two different designs based on frequency (Ka and V band)
  - Microstrip and Stripline
  - Compare with the best available surface-mount RF resistor

Material Options

- Compatible with PTFE-based laminates
- Compatible with PPO-based and other advanced thermosets
- Compatible with Polyimide Flex materials
- Supports microstrip and stripline
- Available across 10–1000 Ω/sq

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Summary: Why Embedded Resistors?

- Lower parasitics → better array accuracy
- Scalable to mmWave
- Higher density, stability, reliability
- 50+ years proven in mission-critical systems
- U.S. manufacturing

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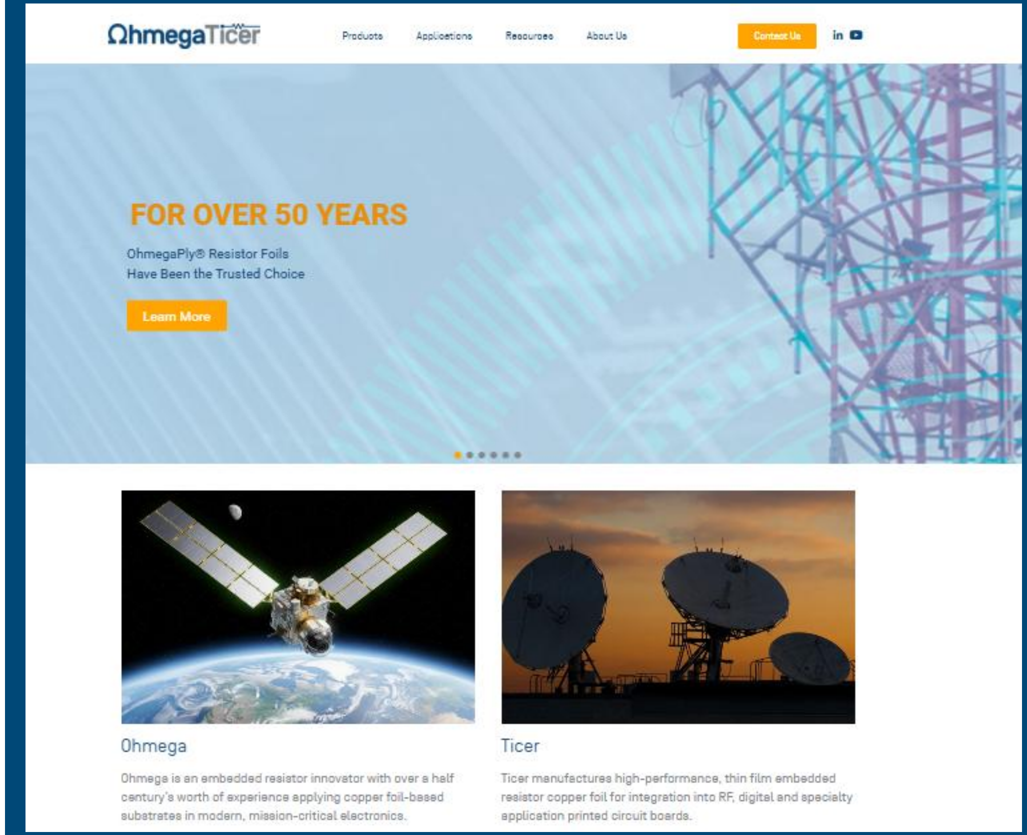
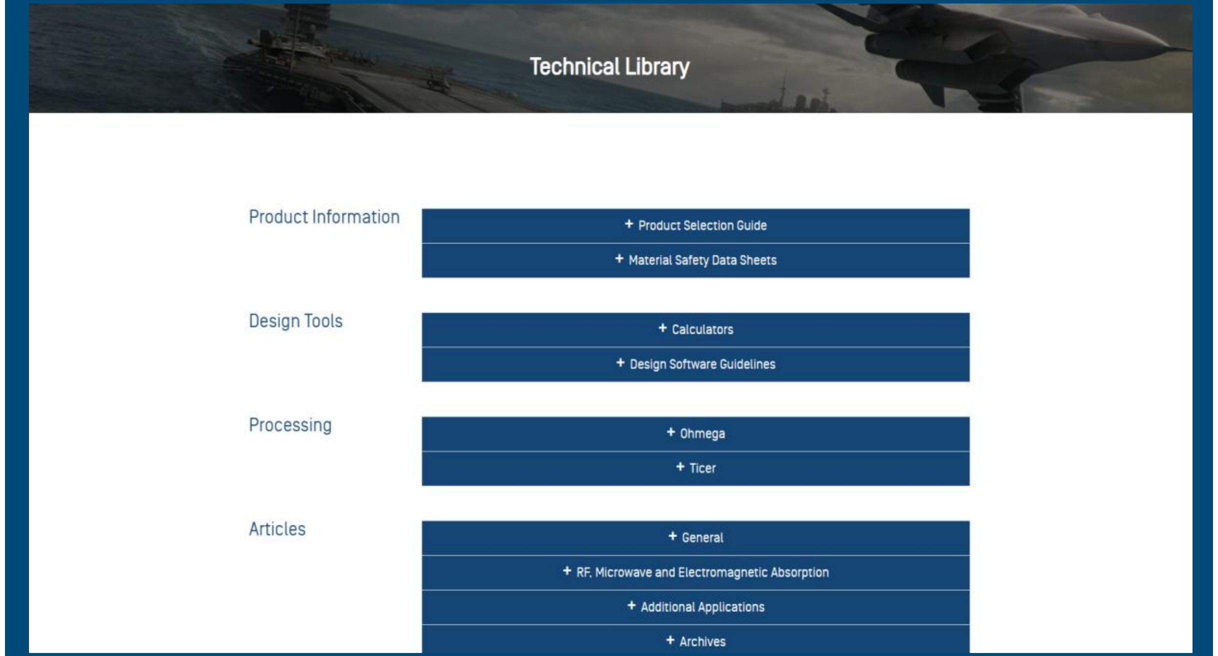


Information on both Ohmega and Ticer product lines



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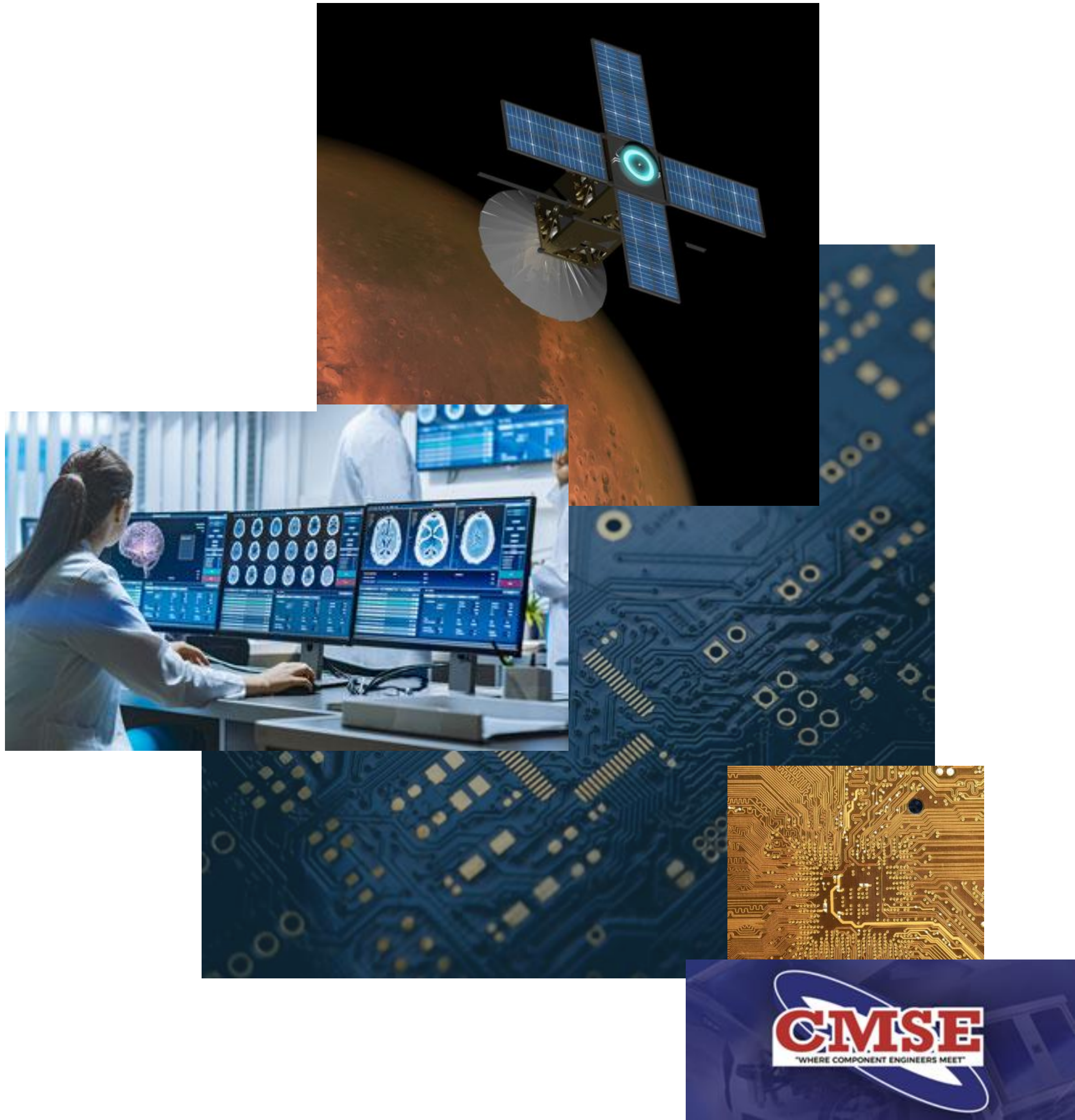
Questions?



Thank You!