New Additive Manufacturing Technology for Space Applications

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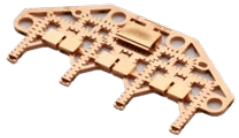
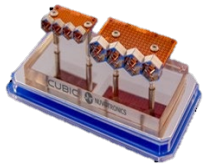
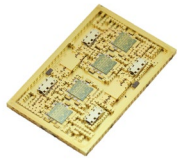
Outline

- Technology Overview
- Basic Building Blocks
- High Q Filtering
- Advanced Packaging
- Space Qualification
- Conclusions

Nuvotronics At A Glance

Filters | Combiners | Antennas | Packages

Inventor and Producer of **Polystrata® Technology:** A unique, and disruptive fabrication process providing the highest performance mmWave compact mmWave components for the **most demanding** Space, Defense, and Test and Measurement customers.

Exceptional RF Performance: Critical RF & mmWave solutions to disrupt multiple markets **6 GHz - 100 GHz+**

Located in Durham, North Carolina

- over **60,000 SF** of manufacturing space
- **37,000 SF** of Clean Room space

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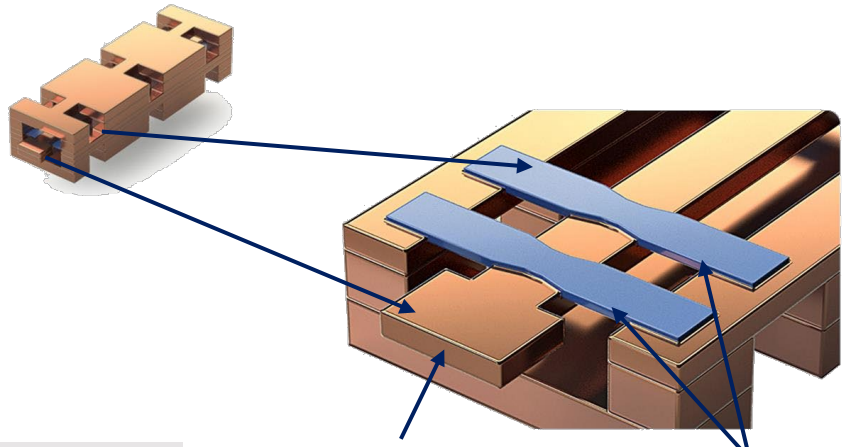
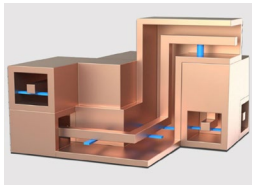
PolyStrata® Technology Overview

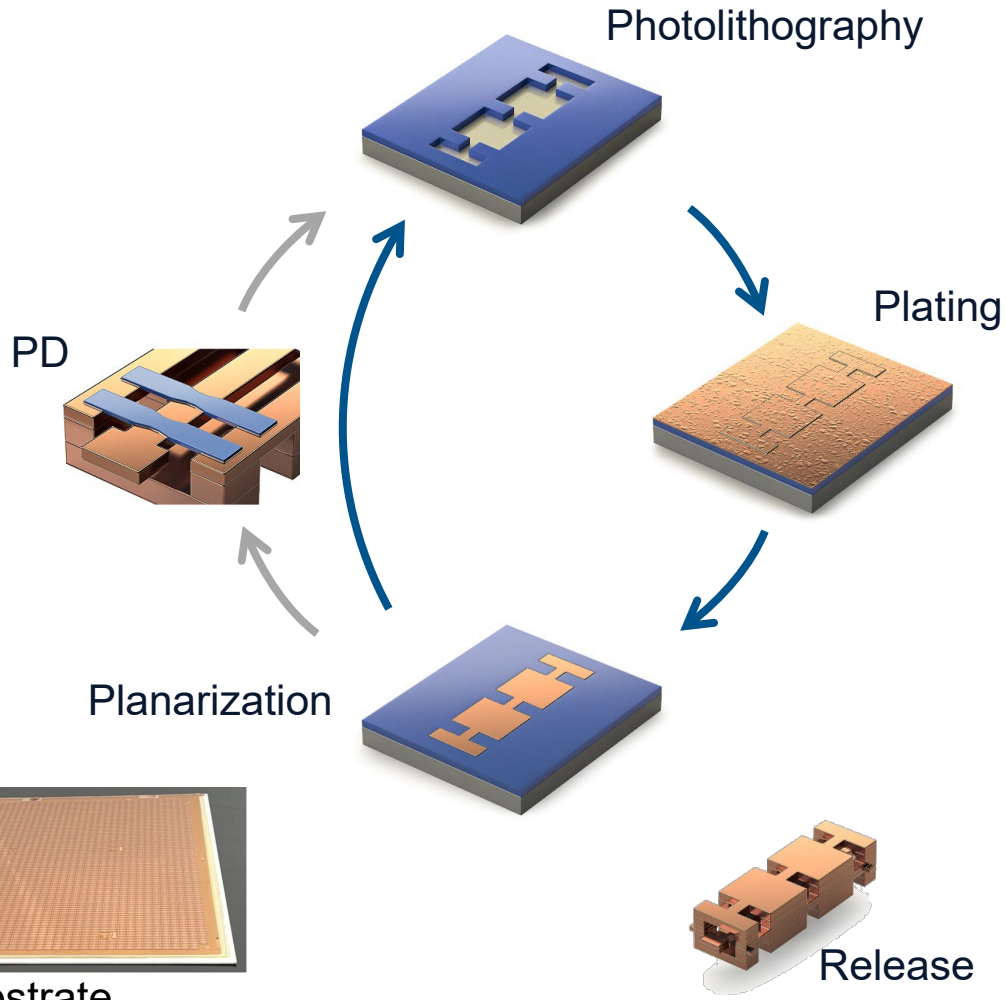




Integrated Air Core
Micro-Coax

- Proprietary Photoresist and Release chemistry
- Hundreds of microns of copper electroplated (up to 2 mm total)
- Micron precision in x,y and z dimensions

Substrate



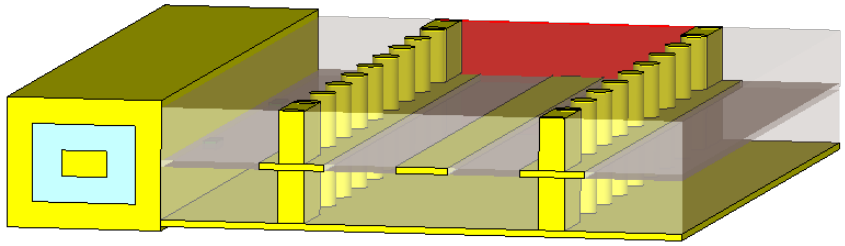
PolyStrata Building Blocks: Micro-Coax

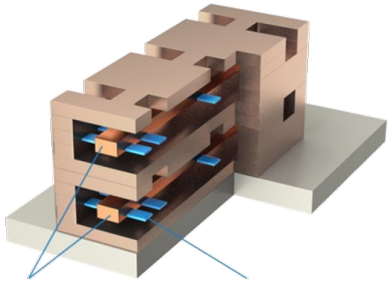
µCoax

- TEM mode
- High line-line isolation
- Multi-layer routing

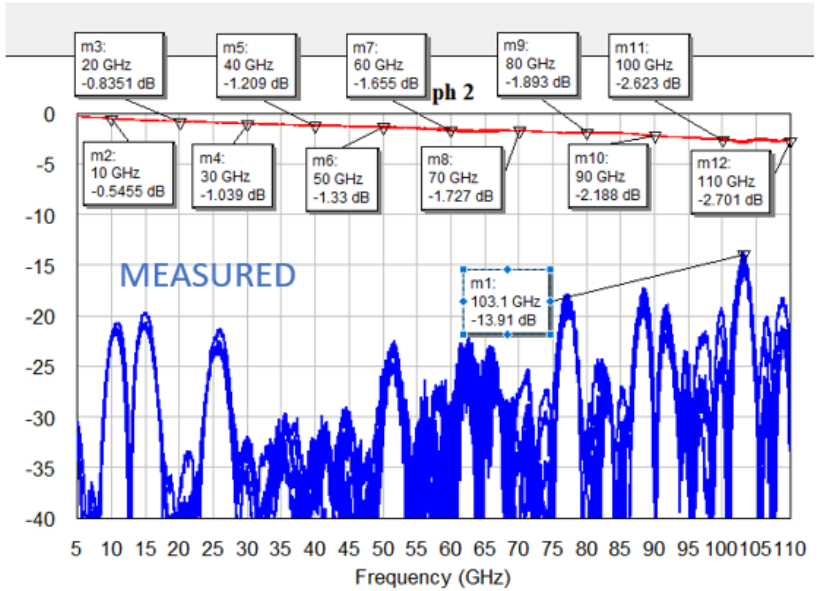
PolyStrata Micro-coax

PCB Stripline

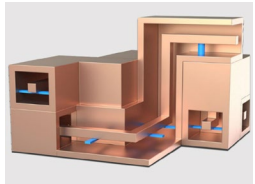




Measured 49mm micro-coax line



	Line Pitch (shared wall/via)	Thickness (shared wall/plane)	dB/cm 11.8 GHz	dB/cm 20 GHz	dB/cm 30 GHz
PolyStrata µ-coax	0.500 mm (0.020”)	0.400 mm (0.016”)	0.092	0.125	0.161
Rogers 4003 Stripline	1.016 mm (0.040”)	0.483 mm (0.019”)	0.116	0.167	0.225

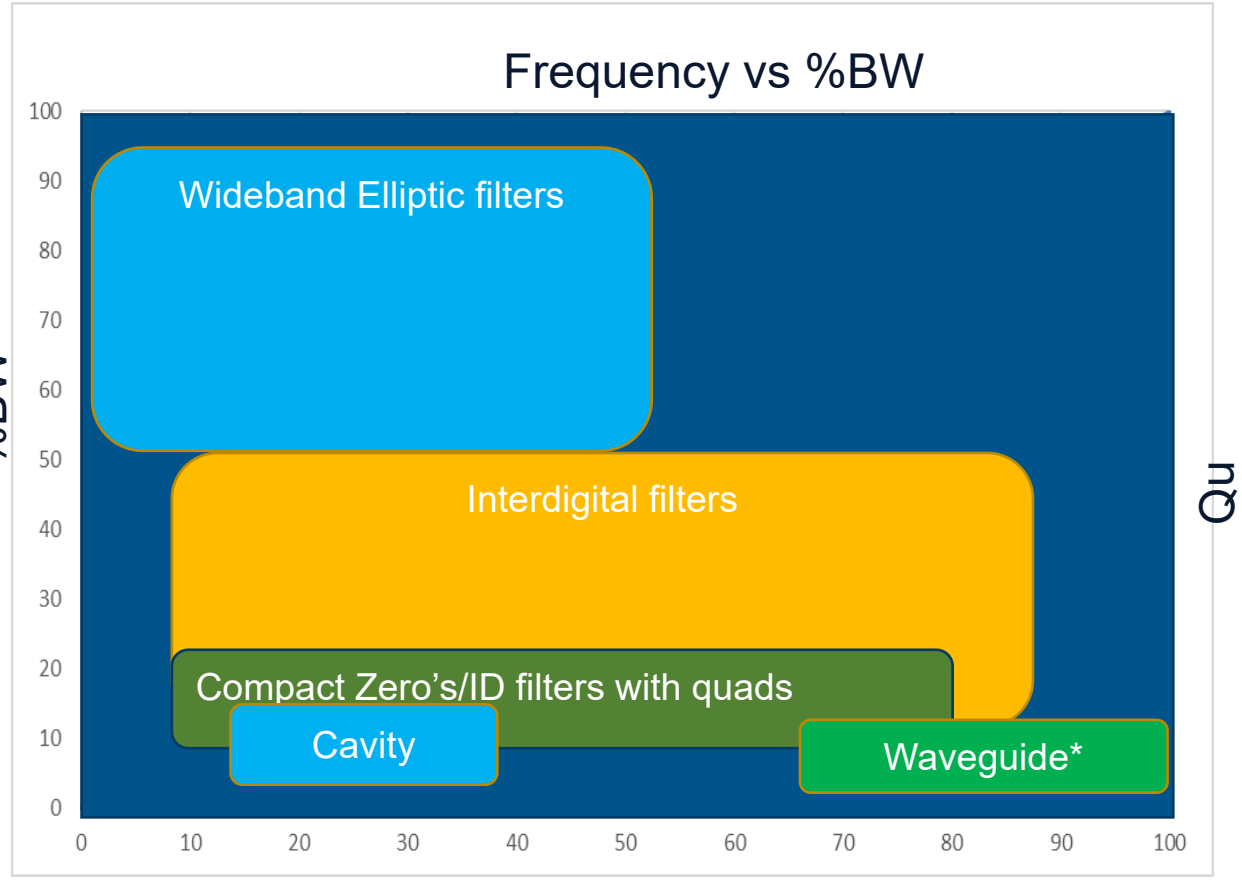


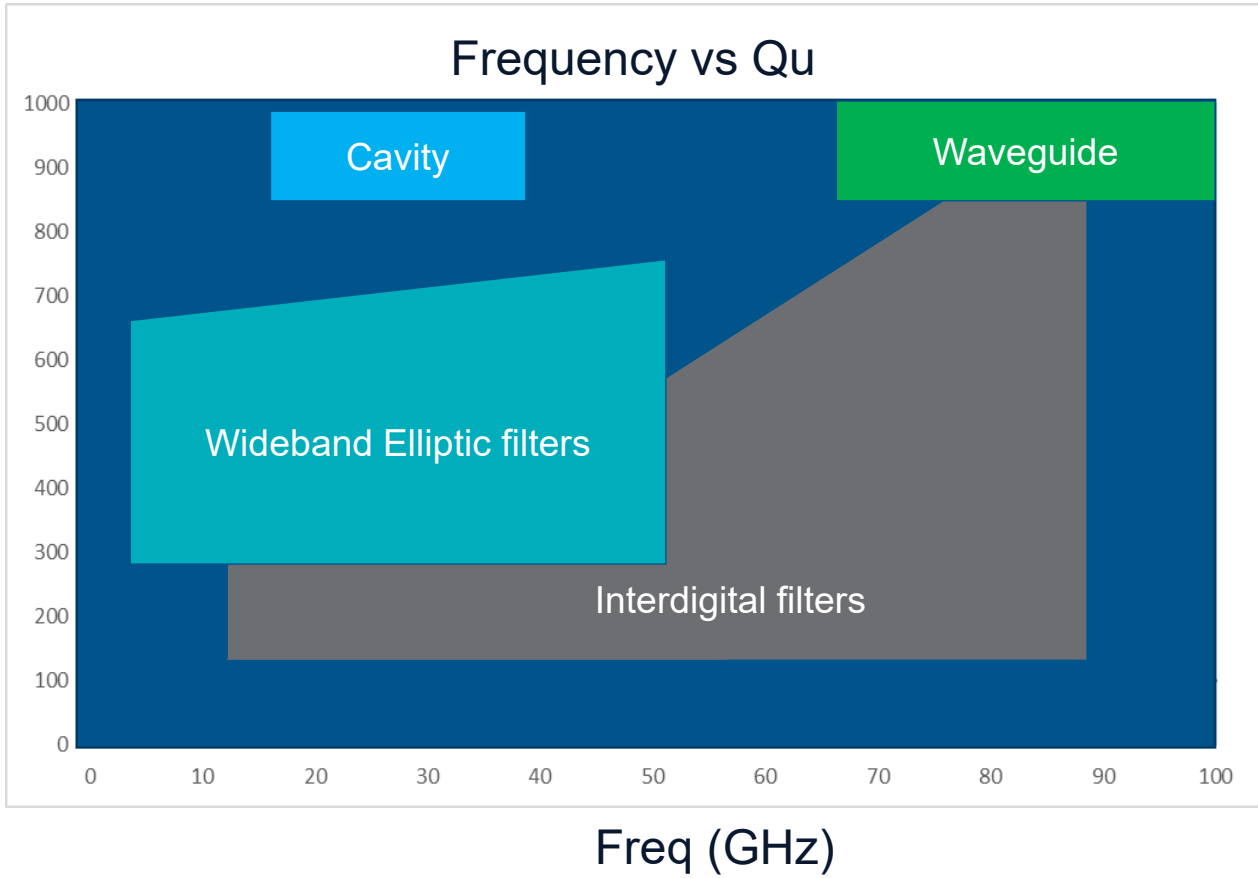
Integrated Air Core Micro-Coax

	loss per 49mm (dB)		loss per 1mm (dB)	
freq. (GHz)	sim	meas	sim	meas
10	0.487	0.546	0.010	0.011
20	0.742	0.835	0.015	0.017
30	0.960	1.039	0.020	0.021
40	1.157	1.209	0.024	0.025
50	1.339	1.330	0.027	0.027
60	1.515	1.655	0.031	0.034
70	1.684	1.727	0.034	0.035
80	1.868	1.893	0.038	0.039
90	2.018	2.188	0.041	0.045
100	2.182	2.623	0.045	0.054
110	2.353	2.701	0.048	0.055

Higher Density Routing with Lower Loss

Filter Topologies Using PolyStrata Technology

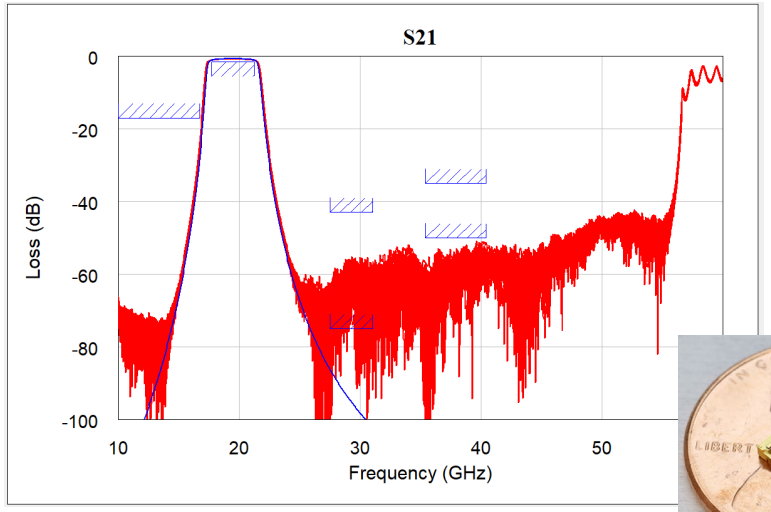


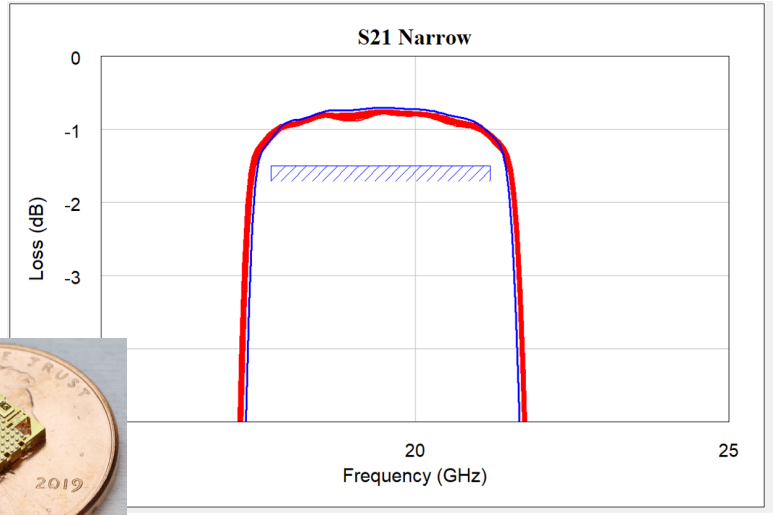


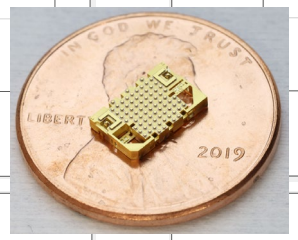
* Have developed WG filters to 670GHz

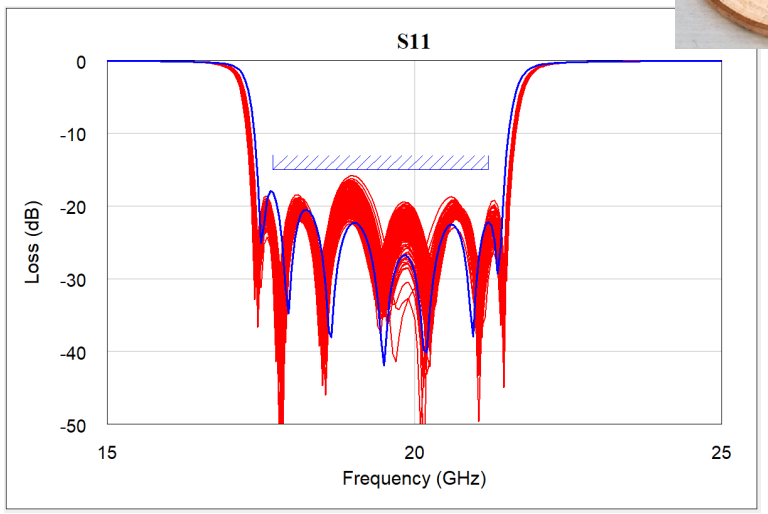
Filter Example: 17.7 – 21.2 GHz Bandpass Filter

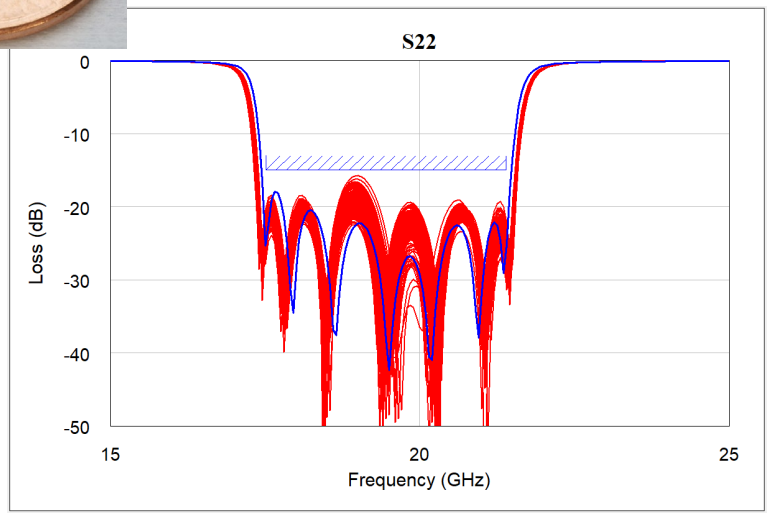
200 Filters Measured on Wafer (Red) Compared to Simulation (Blue)



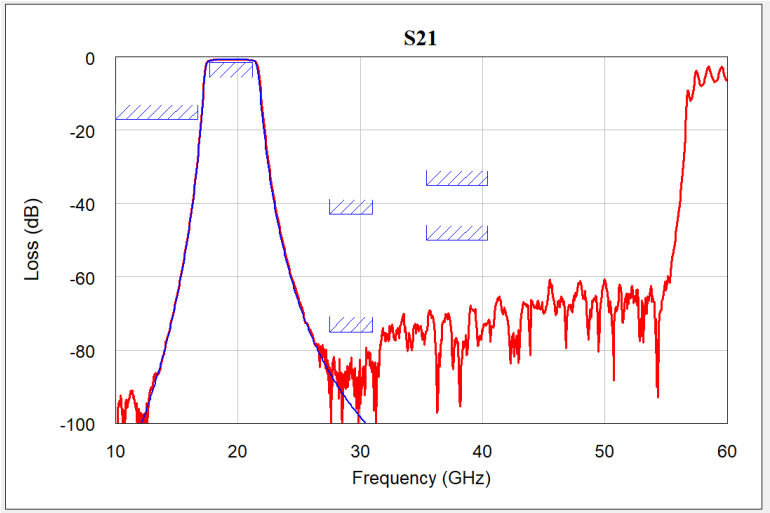


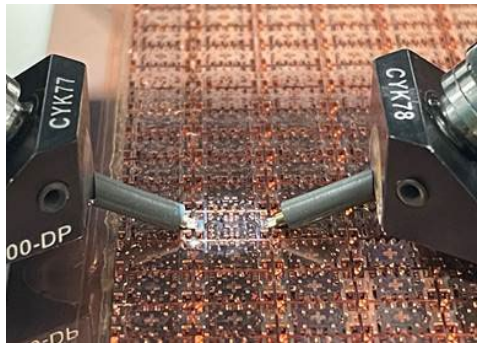


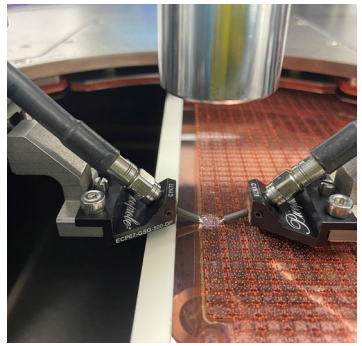




Filter Measured off Wafer in Fixture







On Wafer Test

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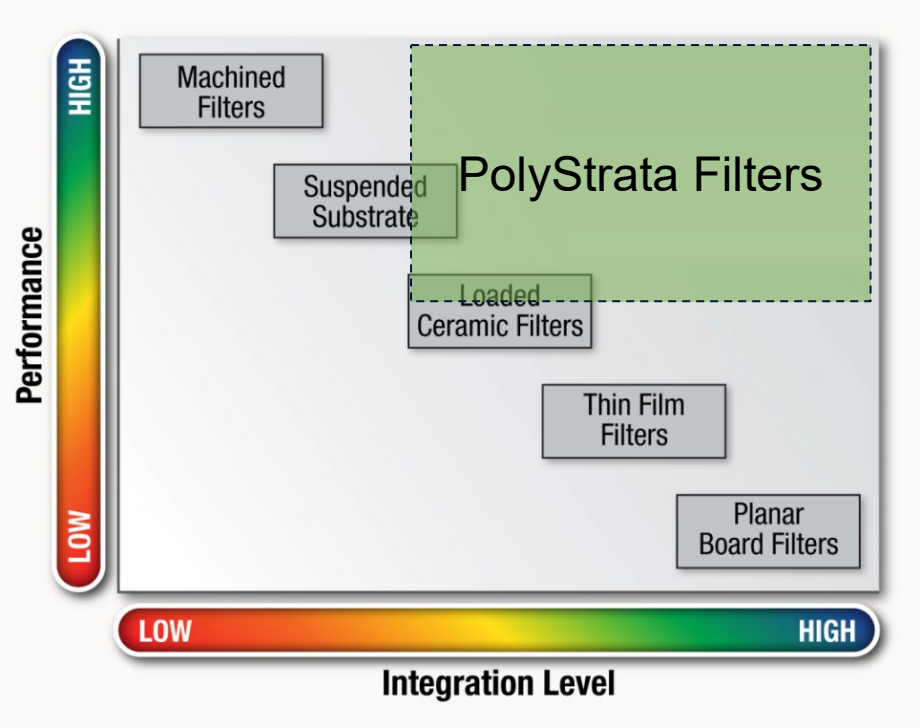
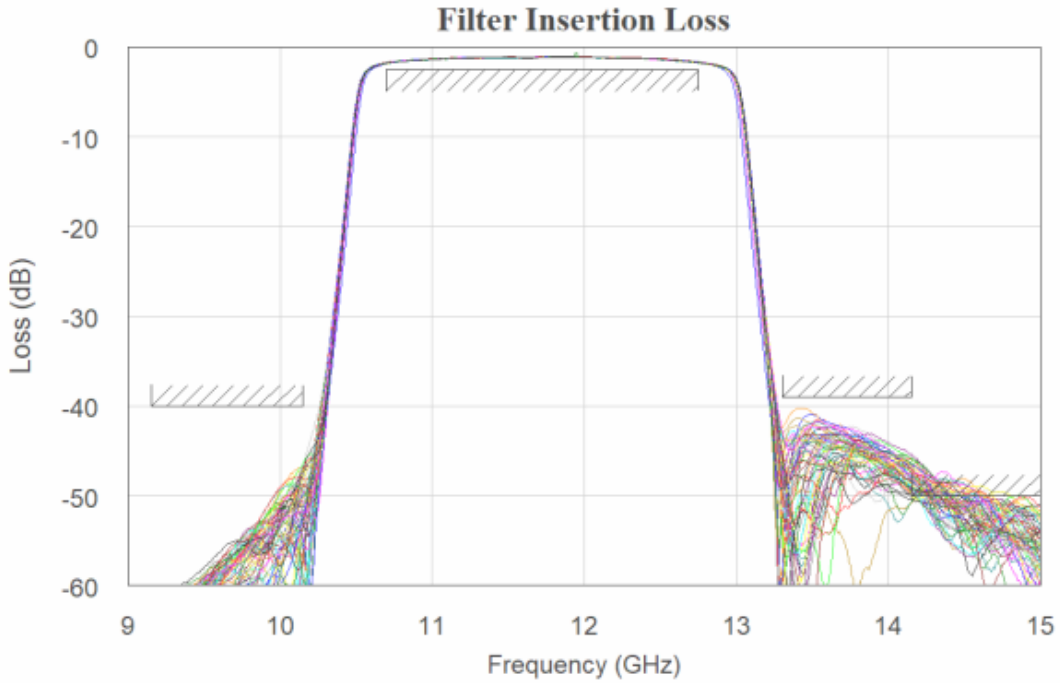
PolyStrata® Filter Summary

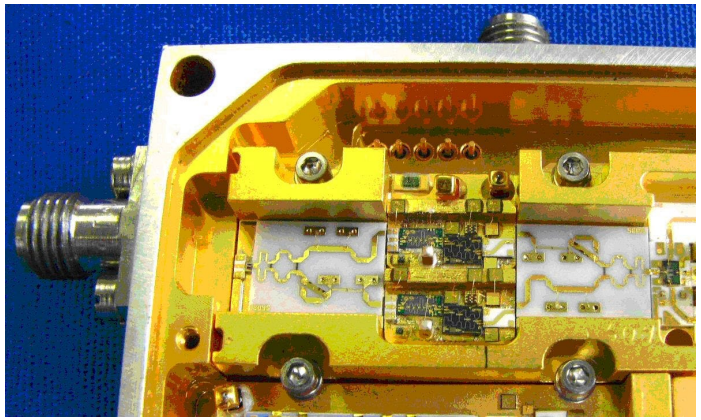
- Performance
  - Air Dielectric
  - Precision copper conductors
- Size and Integration
  - Self-shielded
  - Surface Mount Technology
  - 100x Volume Reduction
- Repeatability and Scalability
  - +/-2 um accuracy of construction
  - Batch process for high volume

PolyStrata® Filters provide both high performance & high integration

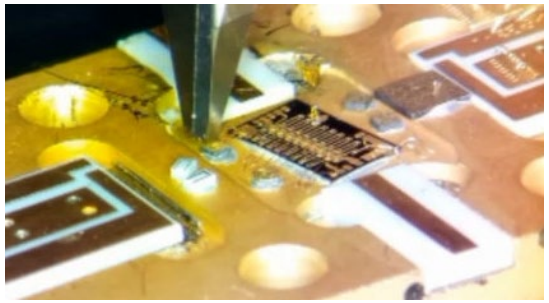




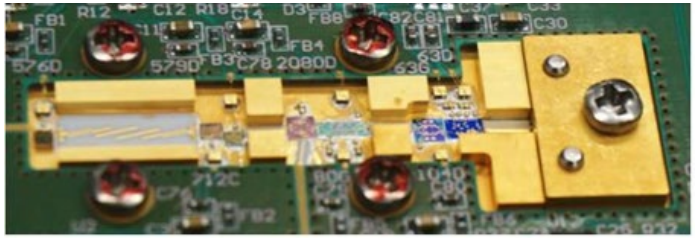
Current State of High Frequency Electronics Manufacturing



Source: Microwaves101



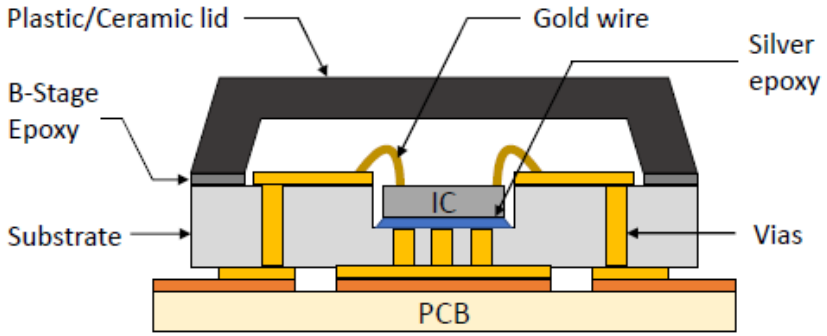
Source: Hesse



Source: Research CSIRO

Current mmWave Assemblies

- Necessary for good performance
- Complex design, complex assembly.
- Challenging repeatability
- High-cost material cost.
- Limited repairability



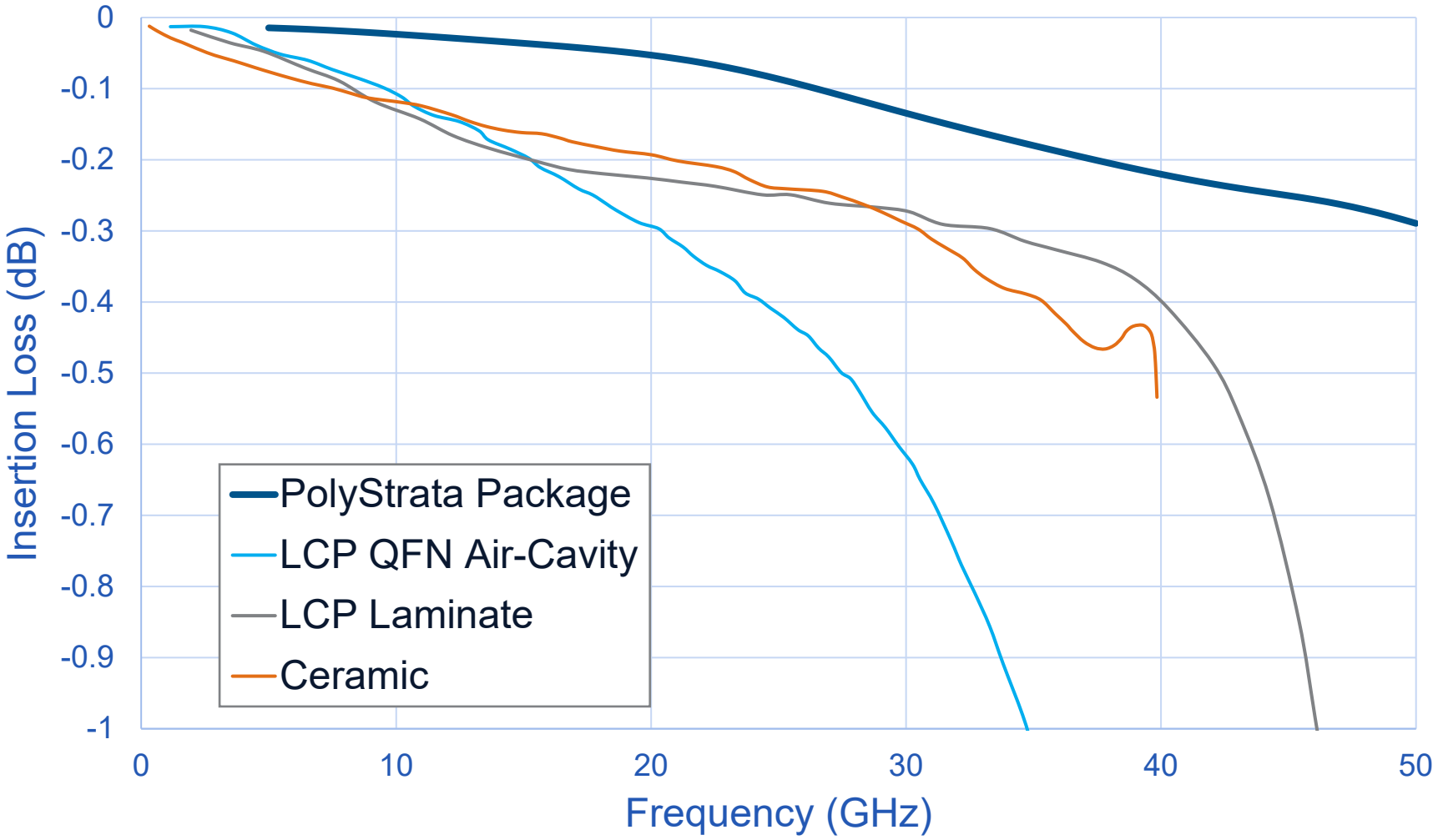
Current SMT Packages

- Parasitics/RF Losses
- Thermal Management

Lack of SMT package devices at frequencies above 20GHz keep designers from using low cost, repeatable modern manufacturing processes.

Current SMT packages degrade IC performance such that many of the benefits are lost.

Competing Package Loss Comparison



A Guide to SMT Packaging of Microwave ICs

Liam Devlin and Andy Dearn

Plextek RF Integration, London Road, Great Chesterford, Essex, CB10 1NY, UK; (liam.devlin@plextekRFI.com)

Broadband, Thin-Film, Liquid Crystal Polymer Air-Cavity Quad Flat No-Lead (QFN) Package

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A Novel High Performance 40GHz Hermetic SMT Ceramic Package for Microwave Applications

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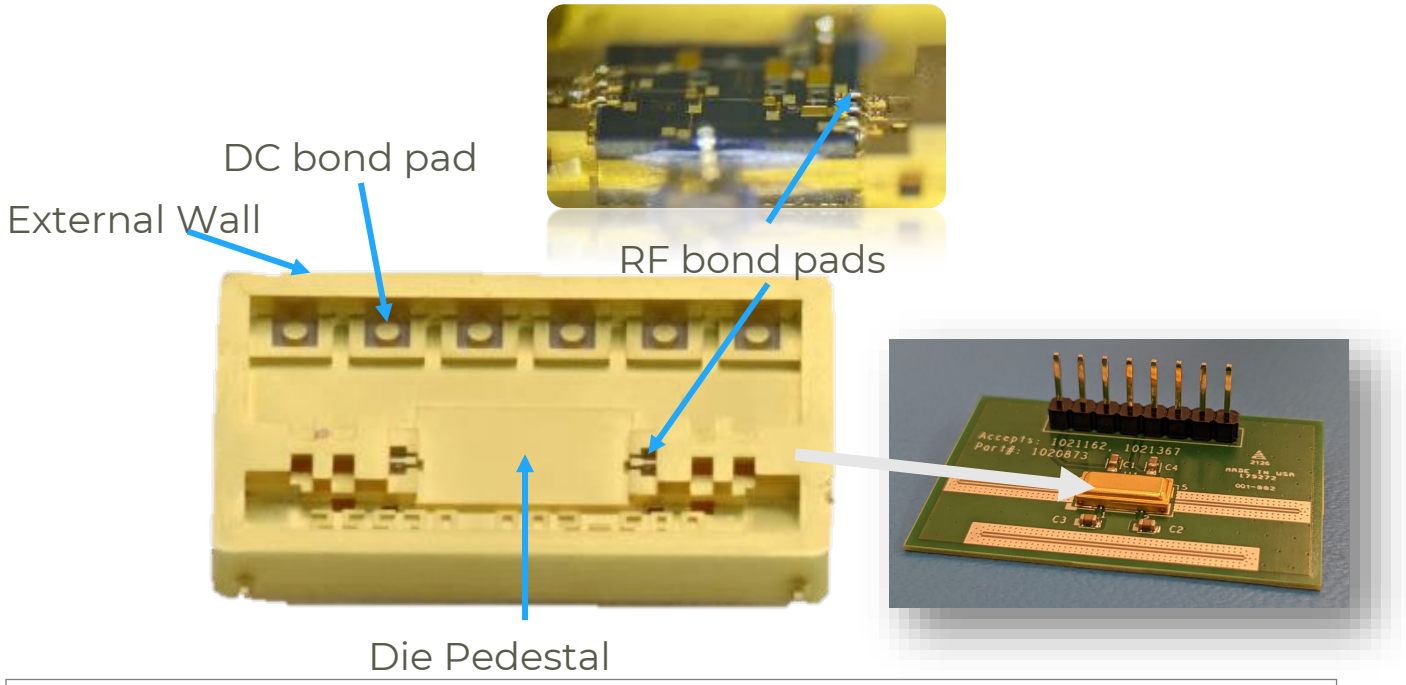
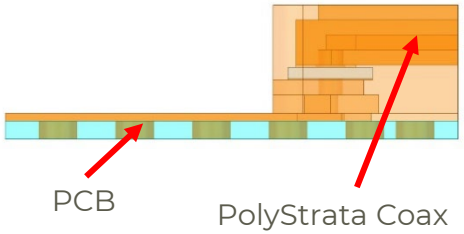
PolyStrata® Packages

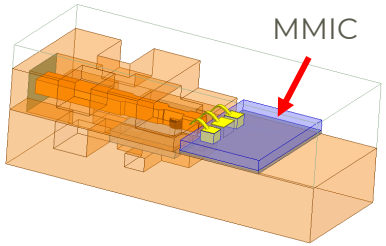


Full 3D Simulated Designs

PCB Transition



Wire bond Transition



Millimeter Wave Packaging Solution

- Air Cavity Package
- Supports entire mmWave spectrum: 15 to +100 GHz.
- Standard die attach and wire bond processes.
- Shielded micro-air-coax.
- Reliable PCB interconnect.
- High thermal conductivity - 400 W/m K

Target Markets

- Space and Backhaul Telecommunications
- Aerospace and Defense
- Test and Measurement

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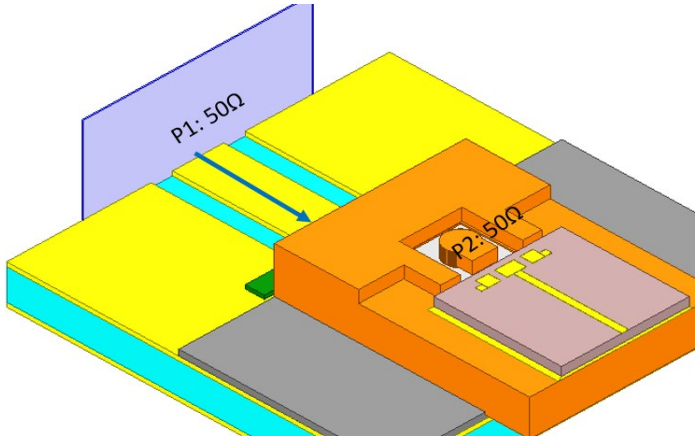
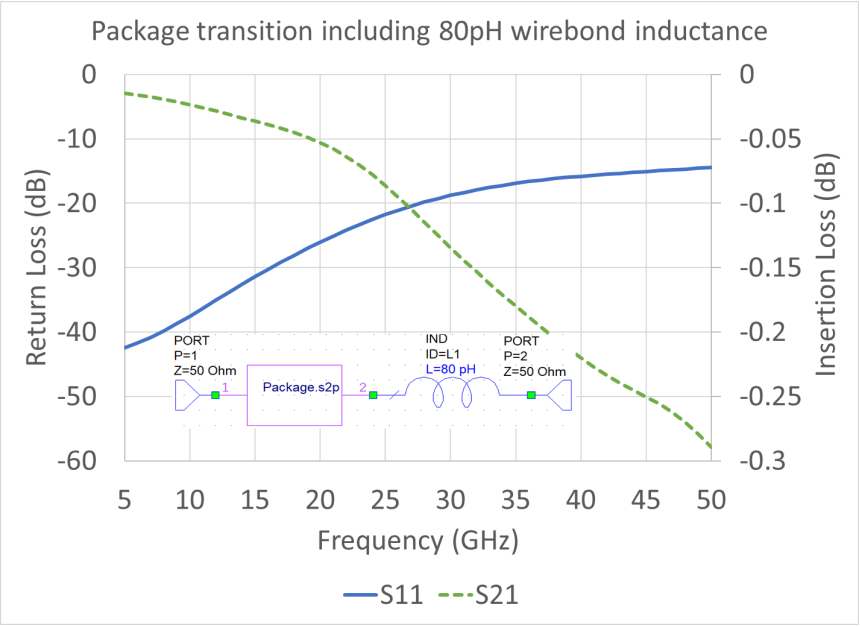
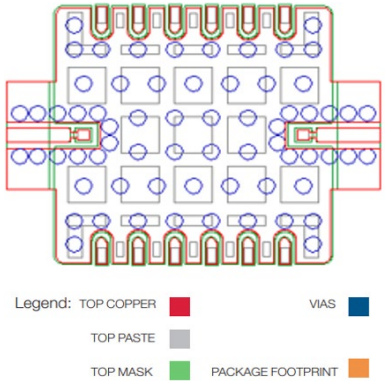
PolyStrata S-parameters detail



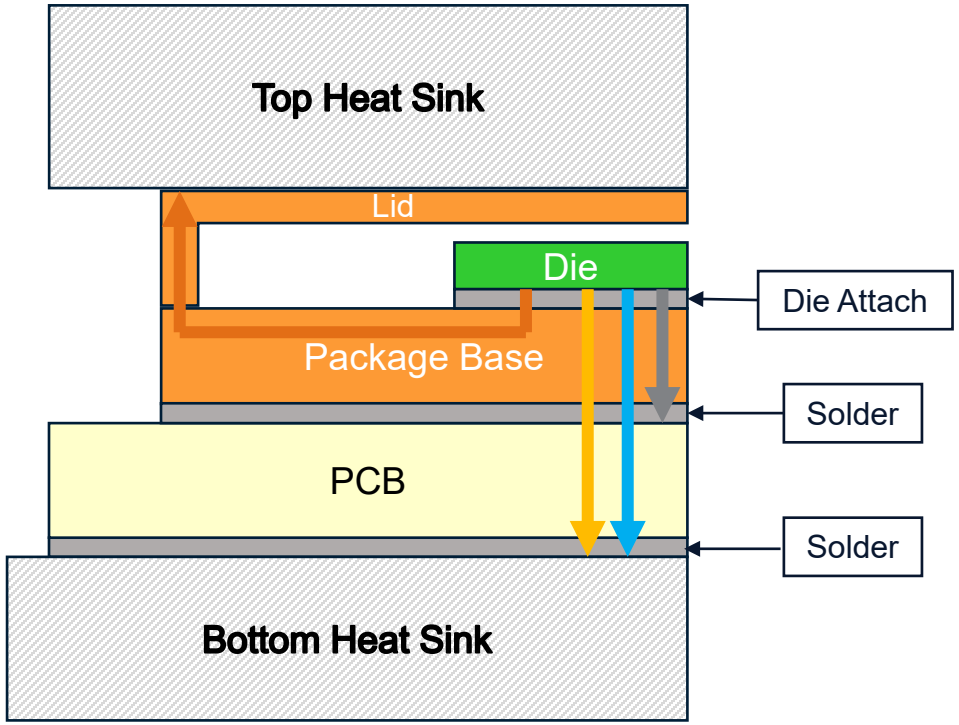
To approximate the wire bonds, an 80pH inductance is included in the plot for Return Loss and Insertion Loss (right figure).



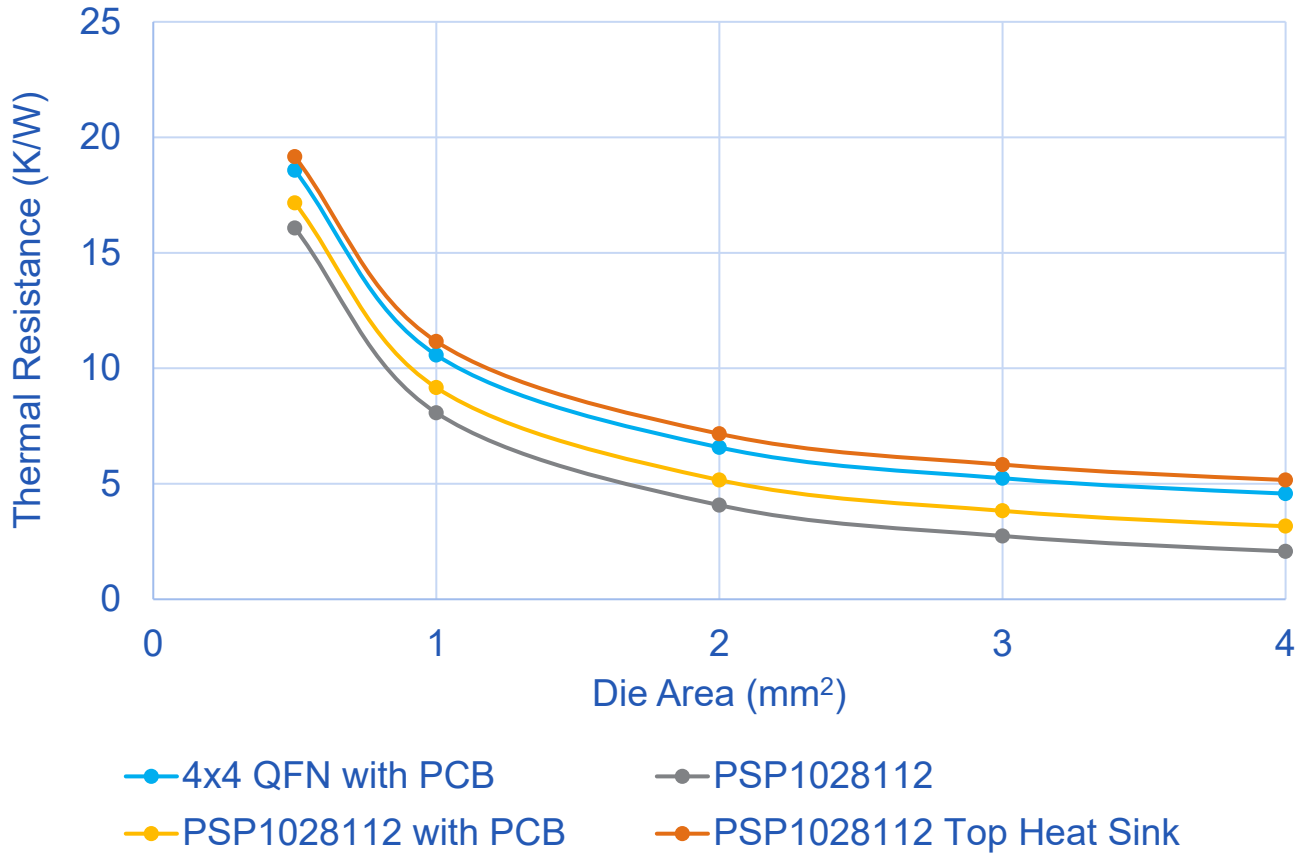


PCB Stack-up

Thermal Performance Comparison



Typical QFN and PolyStrata Package Thermal Resistance comparison: Various size GaAs Die bonded to 4x4 size package.
Thermal Conductivities (W/mK): QFN – 260, Solder – 50, PolyStrata – 393, Lid – 393, Die attach – 2.5, Motherboard – Via # dependent



Reliability tests

Typical Test for Ceramic Packages (package only)

Temp Cycle - -55-125C 1000 cycles
High Temp storage - 150C 1000hrs
High Humidity – 85C/85RH 1000hr OR 130C/85RH 96 hrs

PolyStrata Environmental Test Results

- Unbiased High Humidity – 130C, 85% RH, 96hrs. – Pass
- Thermal Cycling - -55C to 125C, 700 cycles - Pass
- Mechanical Shock – 1500g, 0.5 ms - Pass
- Vibration – 20G, 20-2000Hz - Pass
- Moisture Sensitivity – MSL1, 85C/85%RH, 3 solder reflows – Pass
- Solderability Test – Steamage + solder wetting evaluation – Pass
- Board Reliability – -55C to 125C, 1000cycles - Pass

Package Only Tests

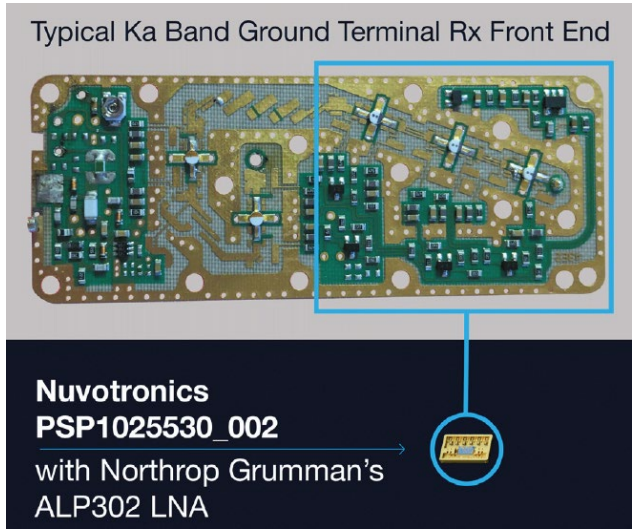
- Moisture Sensitivity – MSL1, 85C/85%RH, 3 solder reflows – Pass
- Gold finish wire bondability test – 300C 1hr - Pass
- Solderability Test – Steamage + solder wetting evaluation – On going
- MIL-STD-883 – Salt Atmosphere – On going
- MIL-STD-883 TM1014 Cond. A4 - Fine Leak Test – On going

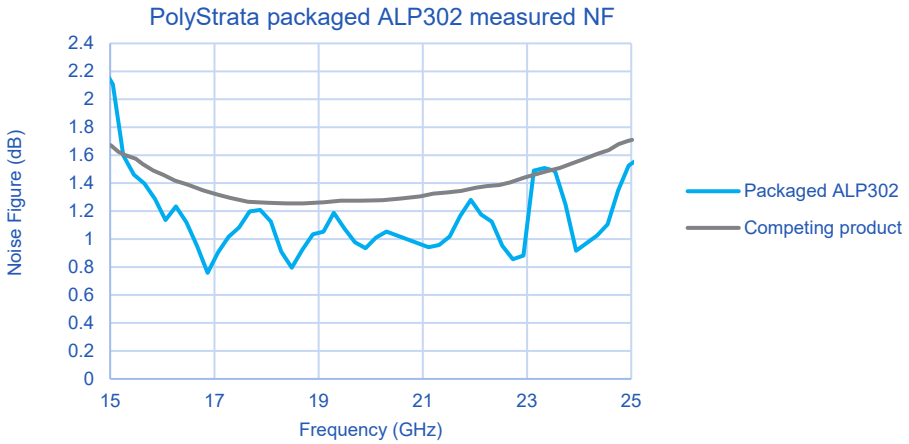
Active Package Tests

- 85C/85%RH for 168 hrs, 3 reflowm using Qorvo CMD247 (20-40GHz LNA) - Pass

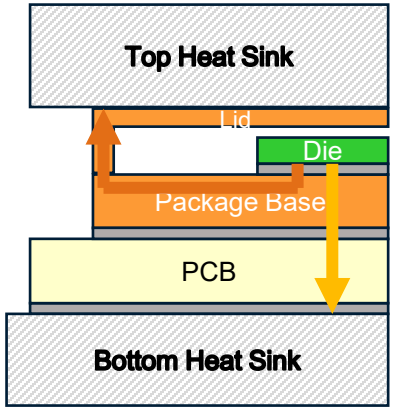
Examples

Ka-Band LNA: RF Performance

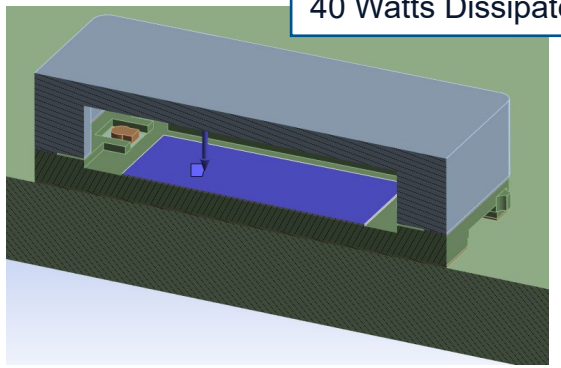




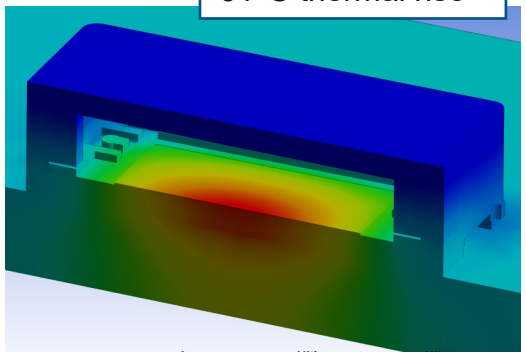
Power Amplifier Thermal Performance



40 Watts Dissipated Power



61°C thermal rise



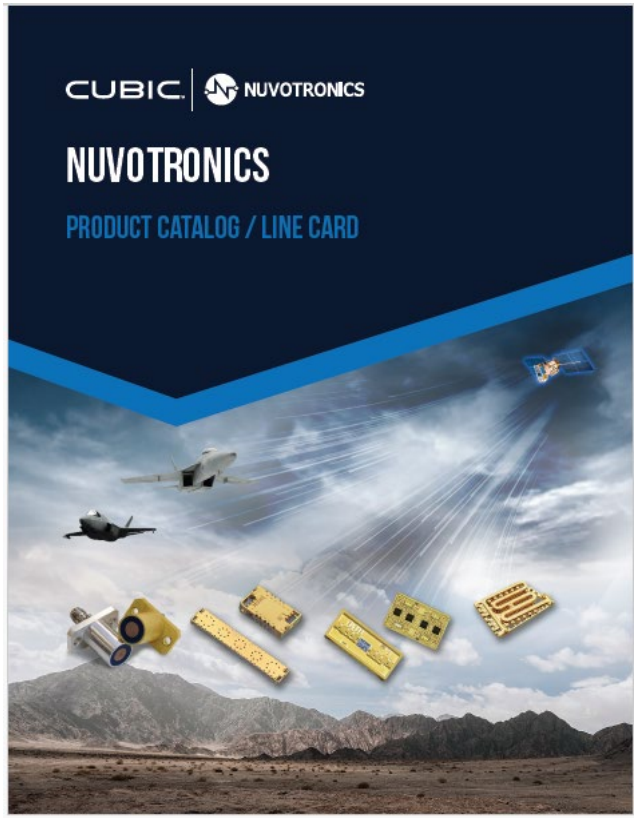
Summary of Environmental Testing of PolyStrata® Components & Assemblies

Environment	Method	Test Details	
Temperature Shock	IPC-TM-650, Cond D	• -55°C to +125°C, • 15 min. dwell at each extreme • 1000 cycles	PASS
Random Vibration	Mil-Std-883 M2026 Cond E (mod)	• 20 Hz – 2000 Hz, 15.51 G_{rms} • 12 minutes each axis	PASS
Mechanical Shock	Mil-Std-883 M2002 Cond. A (mod)	• 1500g, ½ sine 0.75 ms pulse	PASS
Radiation (TID)	Mil-Std-883 M1019.9 Cond. C	• 200 kRad(Si)	PASS
Atomic Oxygen	ASTM E2089	• $2x10^{19}$ AO/cm^2	PASS
Outgassing	ASTM E595	• TML < 1.00% • CVCM < 0.10%	PASS
Temperature Humidity	Custom	• 85ºC / 85%RH, 225 hrs. un-biased • 10-year storage equivalent • Surface finish: bare Cu, ImAg,	PASS

Conclusion

- PolyStrata technology is a good fit for space applications and now has space heritage
  - Includes a wide range of features that are used in PolyStrata filters and PolyStrata assemblies:
  - Polystrata (routing of a wide range of lines and filters)
  - Polystrata to Polystrata stacking (epoxy layer, bare copper parts)
  - Solder attached SMT resistors line to line (eg for Wilkinson combiners)
  - Solder attached capacitors
  - Blind mate attached connectors (epoxy to ground, soldered pin to center conductor)
- PolyStrata technology provides needed functionality and performance with reduced size and weight
  - Filters, baluns, couplers, and combiners
  - Die packaging and multi-chip modules
- PolyStrata technology scales to support large constellations

Thank You



SCAN ME

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