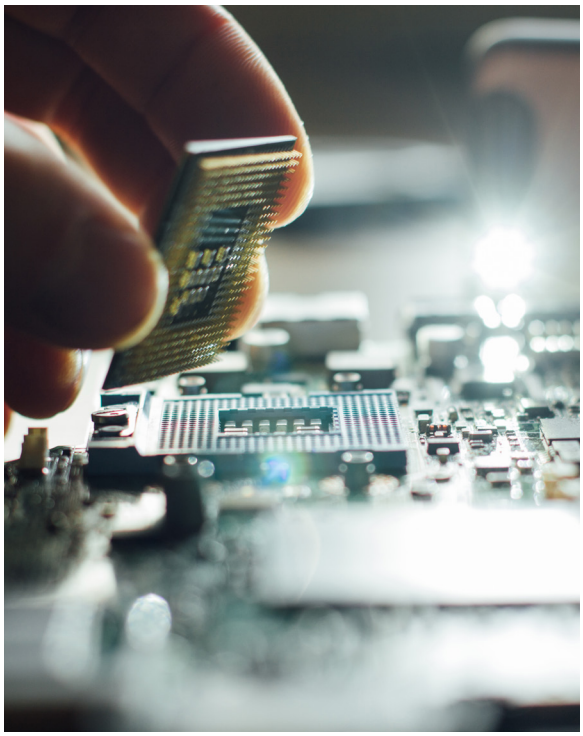
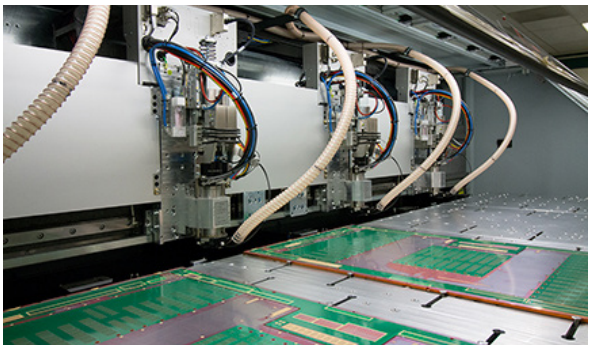
Amphenol PRINTED CIRCUITS

Amphenol SV MICROWAVE





RF PCB CAPABILITIES

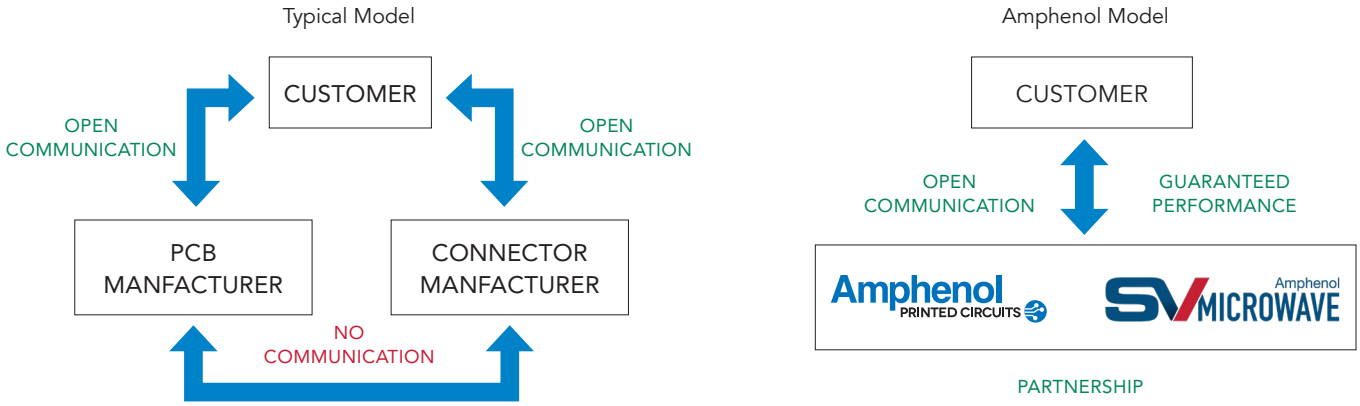
Amphenol Military & Aerospace Operations

TABLE OF CONTENTS

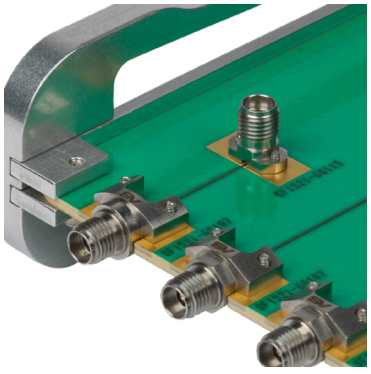
Your **One-Stop-Shop** for RF PCB Design and Build.

In the Defense industry, designing and manufacturing RF printed circuit boards is no simple feat. Traditional PCB manufacturers have a high degree of specialization in PCB material design and development and fabrication tolerances and techniques. However, they have limited knowledge when it comes to connector selection, design and launch techniques. Conversely, RF connector manufacturers specialize in design and manufacturing of PCB mount connectors with little input to the PCB design. The end integrator is often left to put the pieces together, and there is no guarantee of a satisfactory end result.

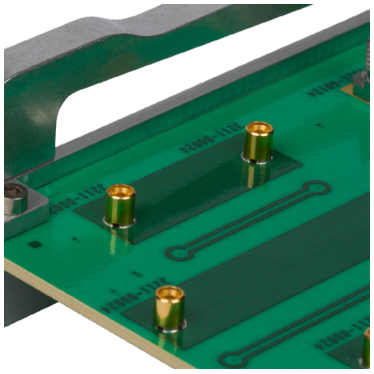
Amphenol is in a unique position to provide a value-add solution to the Prime Contractor by combining the expertise of the PCB manufacturer (Amphenol Printed Circuits) and the Connector Manufacturer (Amphenol SV Microwave) to supply a guaranteed, tested and confirmed end product.



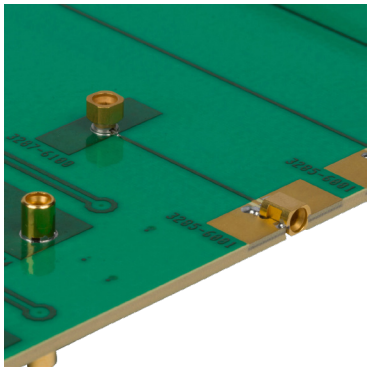
As a demonstration vehicle, Amphenol SV Microwave and Amphenol Printed Circuits have teamed up to create a high performance RF test demonstration board. This board showcases some of our most advanced joint-capabilities in low loss, high performance RF connectors and PCB materials.



Solderless Edge Launch and Top Launch 2.92 mm Connectors on 40 GHz Megtron 7N Core



SMPM Surface Mount Hermetic Connectors on Megtraon 7N with UltraSpeed™ Processing



SMPM Surface Mount and Edge Mount Solder-On Connectors on Microstrip Trace

AMPHENOL BUSINESS UNIT OVERVIEW

Amphenol Printed Circuits

Amphenol Printed Circuits is a technology leader in the PWB industry. We design and manufacture Rigid , Flex, and Rigid Flex PWB's and for Military, Aerospace, Satellite, and Telecommunications applications. Our expertise with advanced materials , process methods, and capabilities allow us to manufacture the most advanced products available on the market.

With over 40 years experience and headquartered in Nashua, NH we provide state-of-the-art PWB and PWB Assembly solutions for our customers. Our New Hampshire PWB facility is 218,000 square feet

Amphenol Invotec

Operating from facilities in Tamworth and Telford, Amphenol Invotec is one of Europe's leading manufacturers of time critical, high technology printed circuit boards. Amphenol Invotec manufactures a comprehensive range of multilayer, HDI, sequential lamination, flex and rigid-flex PCBs using a variety of advanced materials, finishes and technologies to meet exacting customer specifications.

Amphenol SV Microwave

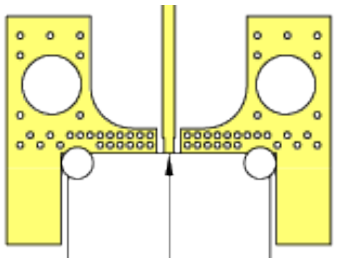
Amphenol SV Microwave is a world leader in the RF/ Microwave industry. We design and manufacture coaxial connectors, cable assemblies and passive components for Military, Aerospace, Satellite, Telecommunications and Test and Instrumentation applications. With over 50 years experience and headquartered in West Palm Beach, FL we provide state-of-the-art connector solutions for our clients.

NO ONE-SIZE-FITS-ALL APPROACH

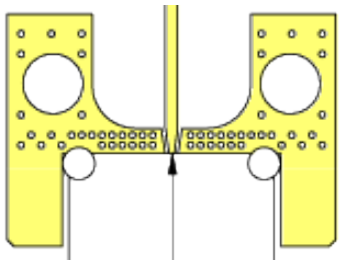
There is No One-Size-Fits-All Approach to High Performance RF PCB to Connector Launches

Many RF connector manufacturers publish 'Recommended Footprints' on their PCB connector datasheets. The caveat here is that the Recommended Footprint is most likely either generic, or designed for a specific stackup only. To truly match a connector to a unique stackup, the footprint must take into account the composition of the PCB. Dielectric core Dk and thickness can play a major role in footprint design for an optimized 50 ohm transition.

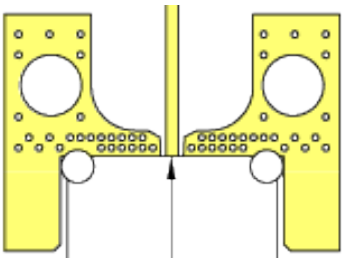
To demonstrate, see the below three traces with three different trace geometries. The minor differences of these traces used on the same circuit board (with all other grounding vias and ground plane geometries being the same) produced three distinctly difference performance results.



Trace 1
Tapered Trace



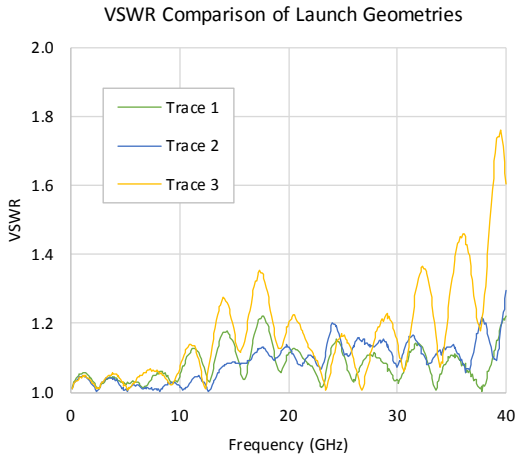
Trace 2
Stepped Trace

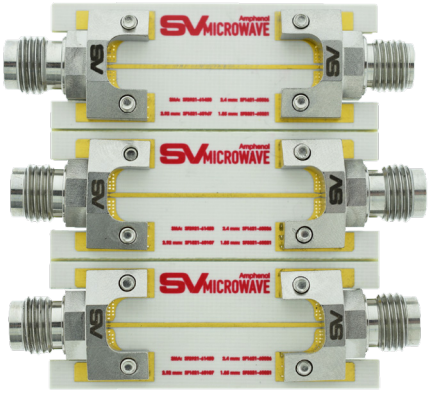


Trace 3
Straight Trace

Below 8 GHz, the three traces have relatively similar performance. As the frequency increases, the simple changes to the trace geometry have a pronounced impact on the RF performance. At 40 GHz the VSWR of the tapered trace is half that of the straight trace.

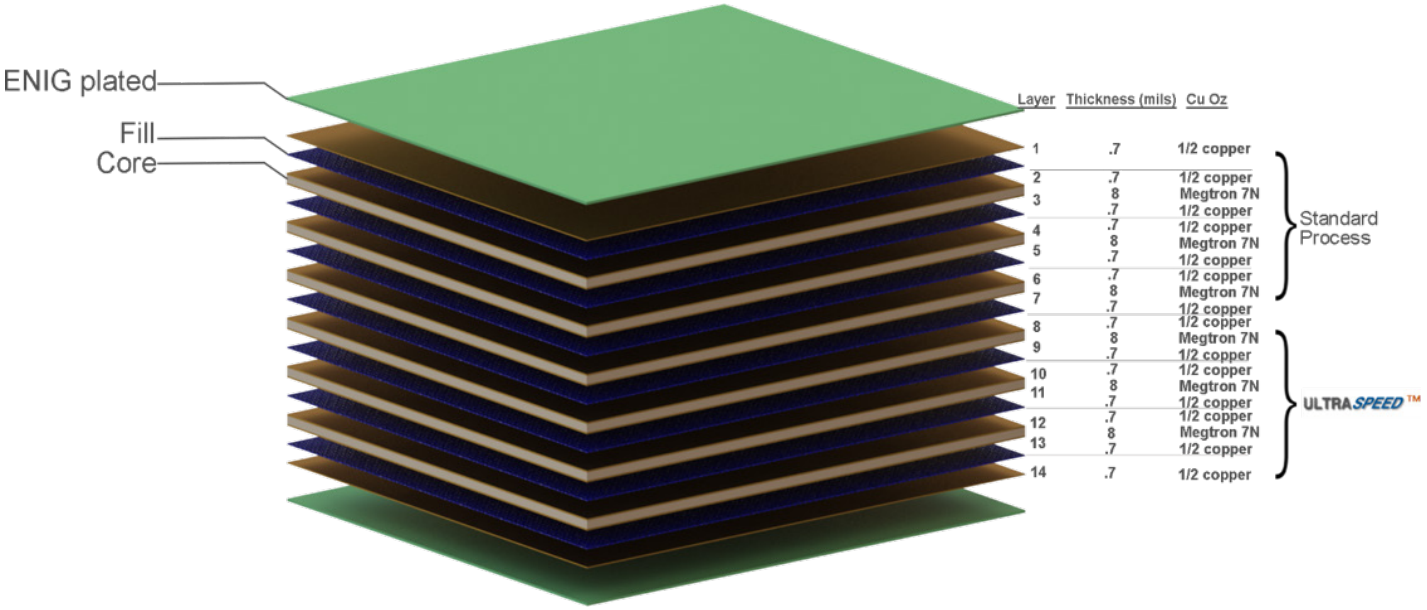
A high performance launch depends on more than just the trace geometry. All aspects of the launch from the via spacing to the copper pullback from the edge to ground plane cutouts must be evaluated in order to create a high performance launch. And these patterns are closely linked to the stackup of the PCB, so there truly is no one-size-fits-all approach when performance is critical.





RF EVALUATION BOARD MATERIAL COMPOSITION

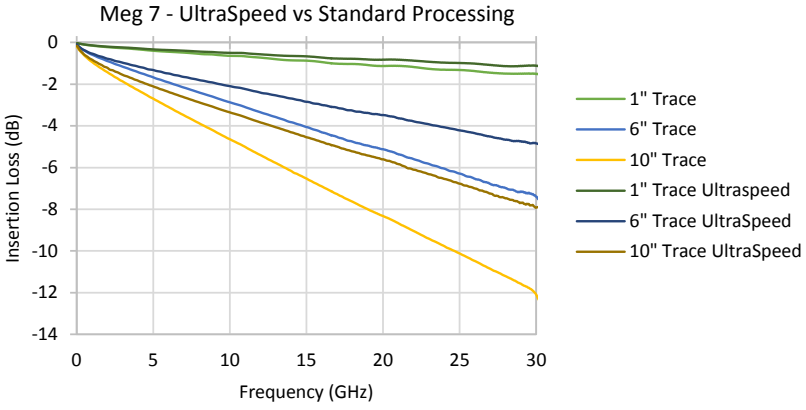
Below is the stackup used for the high performance Evaluation Board. We selected Meg 7N material for this test and developed a stack up that incorporated standard processing and our patented UltraSpeed™ process into one panel for a side by side comparison of loss on identical circuit geometries with the intent of demonstrating overall material capabilities and the potential benefits of incorporating UltraSpeed™ into RF designs.



What is UltraSpeed™?

UltraSpeed™ processing uses a patented technique for controlling the topography of the conductive surfaces of a dielectric core in a printed circuit board. By improving the surface roughness of the copper, lower loss performance can be achieved when compared with standard processing. When combined with Amphenol Printed Circuits industry leading capabilities in Backdrilling, Impedance Control, and Registration, superior RF performance can be achieved.

Please see page 12 for even more information on Amphenol's proprietary UltraSpeed™ technique.



LAUNCH DEVELOPMENT

Through the use of microwave simulation software and iterative design, our EEs develop the ideal footprint for our customers application. In the simulation file, the RF connector is broken down into its core components. Basic steps for launch optimization are highlighted below:

Step 1: Submit Footprint Specification Sheet
In order to complete a launch simulation, it is imperative that our Electrical Engineers have an accurate PCB stackup. Parameters such as core thickness and dielectric constant influence the launch geometry. To obtain optimal RF performance, a one-size-fits-all approach to footprint design must be avoided.

Our 'PCB Footprint Request Form' can be found on our website at www.svmicro.com under the Resources -> Application Notes tab. Key product parameters are identified in this document including:

- PCB Dielectric Core Type (thickness and Dk)
- Transmission line type (CPW, Stripline, Microstrip, etc)
- Attach method (end launch, surface mount, through hole)
- Min via pad size and distance from feature/edge

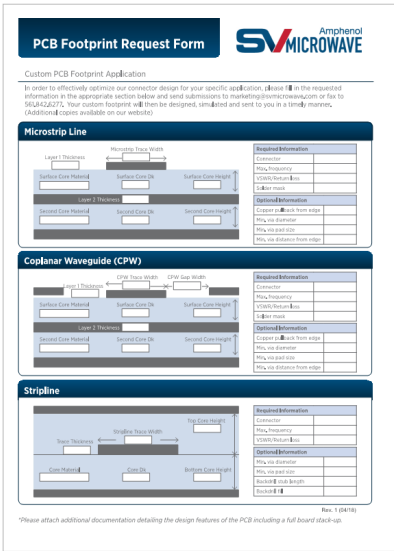


Figure 1
PCB Footprint Request Form

Step 2: SV Engineering Creates First Pass Footprint
Our footprints typically start with a reference to a pre-existing design which we work from. By breaking the connector solid model into core transmitting elements, the model is re-drawn in CST Microwave Studio Reference planes are defined as the locations for which the simulation is started and stopped and typically include the PCB mt RF connector and the launch to the trace up to ¼" past the exit of the connector (or until feature pattern transitions to transmission line).

Factors that impact simulation design include:
- Copper layer pullback from PCB edge
- Transmission line impedance accuracy based on calculators
- Tolerance of drilled holes and etched features

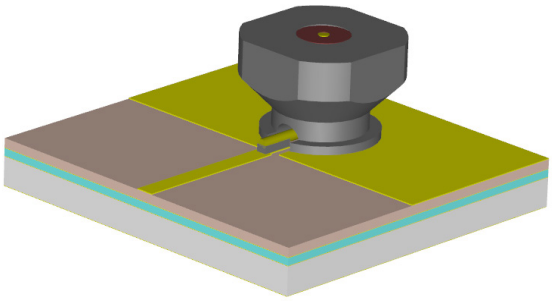


Figure 1.1
CST Electrical Model of SMPM Male PCB Connector
Launching to Microstrip Transmission Line

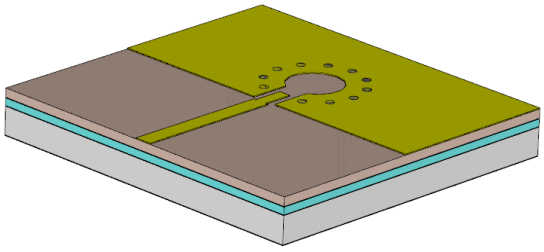


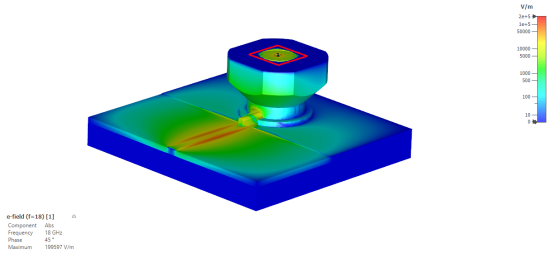
Figure 1.2
CST Electrical Model Showing Footprint
(Connector Removed)

LAUNCH DEVELOPMENT (CONTINUED)

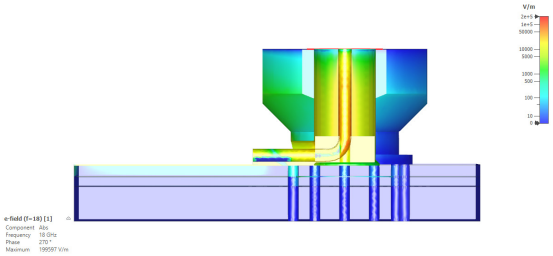
Step 3: Optimization Through Simulation

Mechanical dimensions and features are optimized to simulate the ideal VSWR performance. By tweaking via size and spacing and landing pad geometries, we balance capacitive and inductive spikes to produce a near constant 50 ohm impedance through the launch to PCB. Footprint design is an iterative process and ideal simulation results may not be obtained until the 3rd or 4th design iteration. Often compensation ground plane cutouts in adjacent layers need to be made to balance impedance.

- PCB Dielectric Core Type (thickness and Dk)
- Transmission line type (CPW, Stripline, Microstrip, etc)
- Attach method (end launch, surface mount, through hole)
- Min via pad size and distance from feature/edge

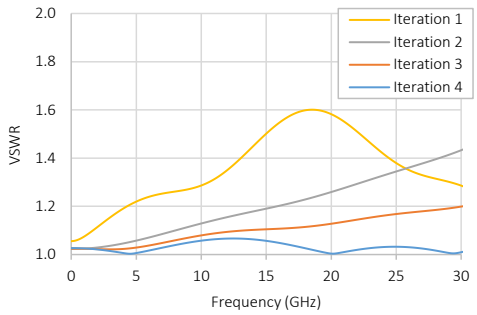


CST Simulation Model Showing
Electric Field Distribution Across Launch

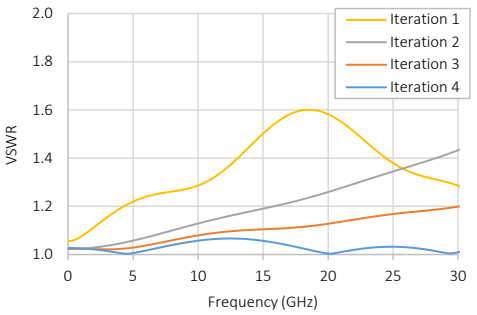


Cross-Section View

Output data is typically a VSWR Simulation Plot which is shared with the customer. General rule of thumb is that the ideal nature of the simulation makes it 25% more aggressive than measured data.



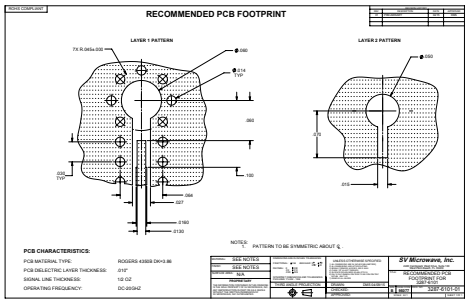
Simulation VSWR vs. Frequency Plot for
3287-6100 Launch to PCB



Simulated Impedance Response
for 3287-6100 Launch to PCB

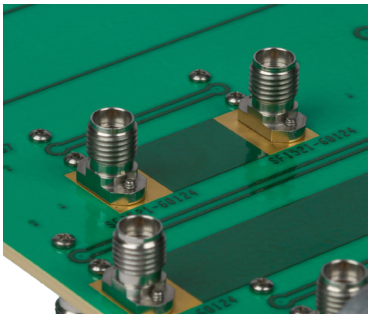
Step 4: Mechanical Drafting

Once the simulation is optimized, the mechanical drawing is drafted in Solidworks including dimensions and tolerances for printed features. On request our engineers can also send .DXF files containing footprint models for integration into customer models. We can output the CST file in .SAT format as well.



MEGTRON 7N ULTRASPEED™ EVAL-BOARD RESULTS

Top View of UltraSpeed™ Side of Eval Board



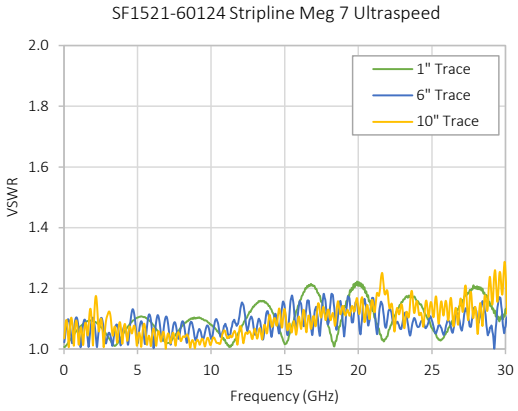
LiteTouch 2.92 mm Connectors

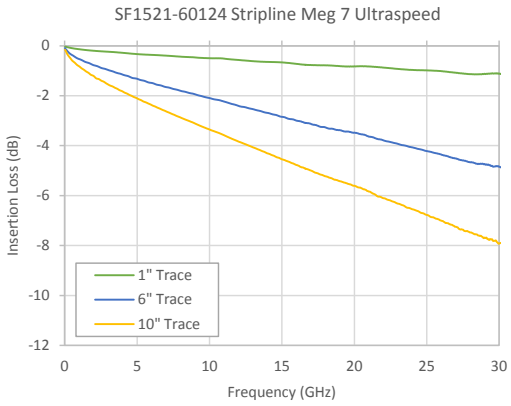
Solderless LiteTouch Stripline Connector Test Results

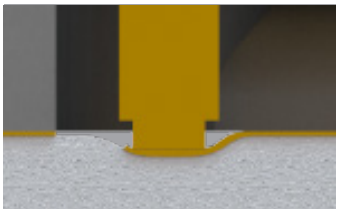
APC and SV Microwave developed the above PCB to demonstrate the proprietary UltraSpeed™ technology combined with a simulated and optimized RF connector launch. This board uses a Megtron 7N core with ground planes processed using the UltraSpeed™ technique.

The Eval Board was tested using SV Microwave's 2.92 mm LiteTouch solderless connector, PN SF1521-60124. LiteTouch is a proprietary interface to SV Microwave designed to minimize return loss by limiting potential damage to the PCB caused by a traditional solderless or 'compression mount' connector interference fit to the PCB.

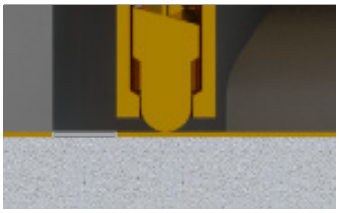
LiteTouch connectors enable high frequency performance through an impedance matched spring pin technology that limits compressive force on the trace.





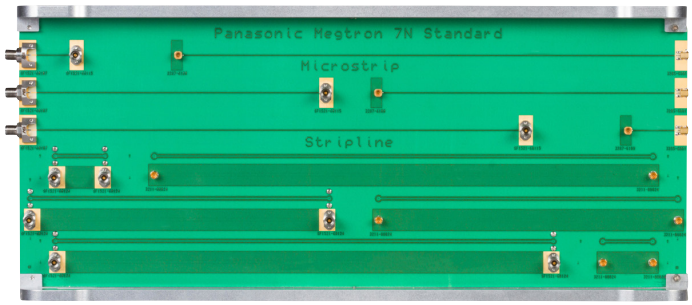


Trace Deformation Caused by Standard Compression Mount Connector

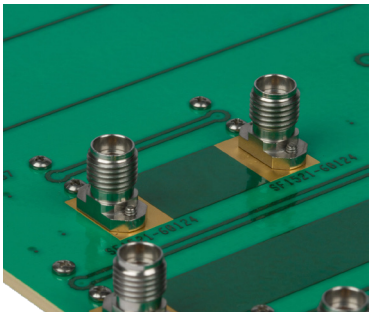


LiteTouch Connector Cross Section Limiting Trace Damage After Mounting

MEGTRON 7N CONVENTIONAL EVAL-BOARD RESULTS

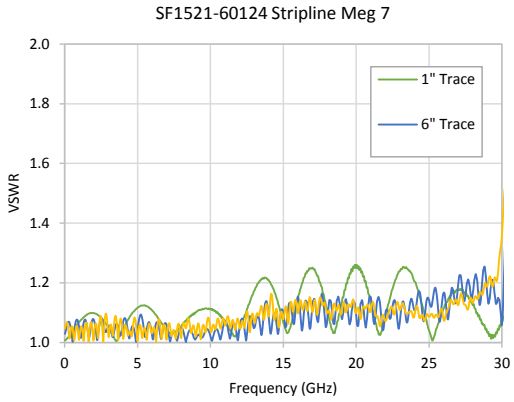


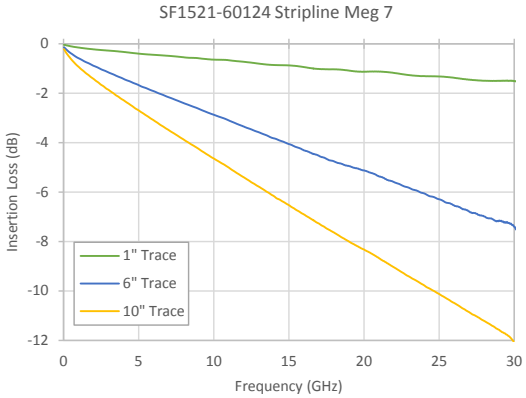
View of Standard Side of Eval Board



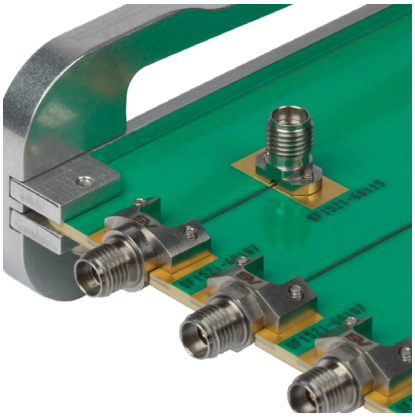
LiteTouch 2.92 mm Connectors

The same test was then performed on a non UltraSpeed™ test board using 2.92 mm LiteTouch Connectors to contrast the performance of the UltraSpeed™ processing technique.

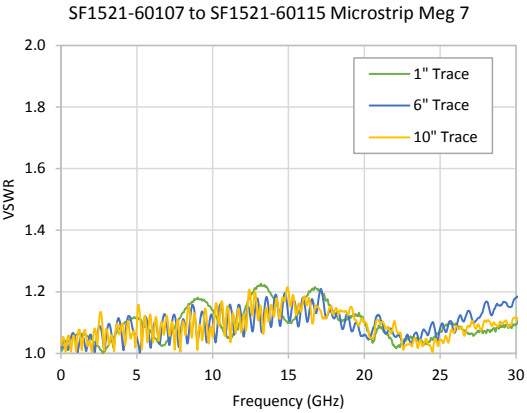




Microstrip traces for evaluating SV Microwave's Solderless Edge Launch Connectors were also developed and tested on the conventional Megtron 7 board. As expected, the VSWR performance of the edge launch was superior to the top launch due to the linear signal transmission of the edge mount connector.



2.92 mm Solderless Edge Mount Connectors

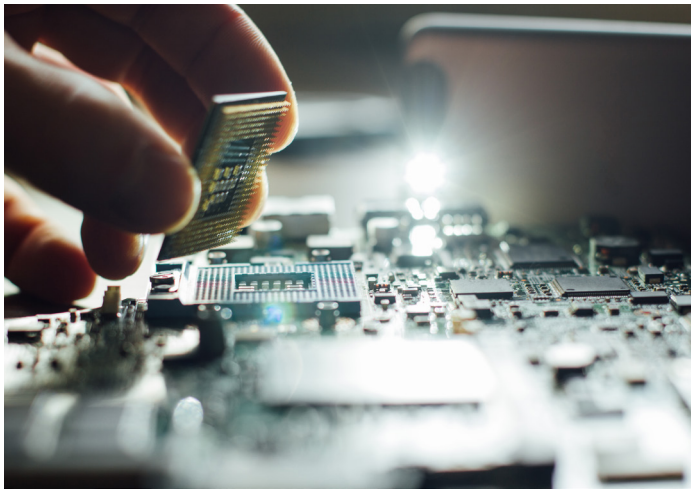


THE AMPHENOL ADVANTAGE

The results of the evaluation board show that high performance RF connector launches to PCB can be achieved when the connector and PCB manufacturer are working together.

…the key Amphenol Advantage is that Amphenol can not only design and build your complex RF PCB, connectors and launch, we can guarantee the RF performance specified by building and testing the PCB prior to shipment.

At Amphenol, we stand behind our performance and capabilities Let us be your partner in high performance RF PCB and connector design and build.



The Amphenol Advantage:

Global footprint, local support:
With 21 divisions in North America, Europe, and Asia, we can provide a local, regional presence to design and build any interconnect solution.

Cost-effective partnerships:
AMAO utilizes a vertically integrated supply chain to flow down the most competitive costs to our customers, even on the most complex solutions.

Manufacturing versatility:
Many AMAO interconnect solutions have dual-production locations and off-set options which means our customers benefit from low-cost options without the fear of a single-source position.

Technology proliferation from other Amphenol divisions:
As the 2nd largest interconnect company in the world, we're highly diversified and can provide our proven COTS technology from the antennas, sensors, industrial, and automotive markets to the military and aerospace world.

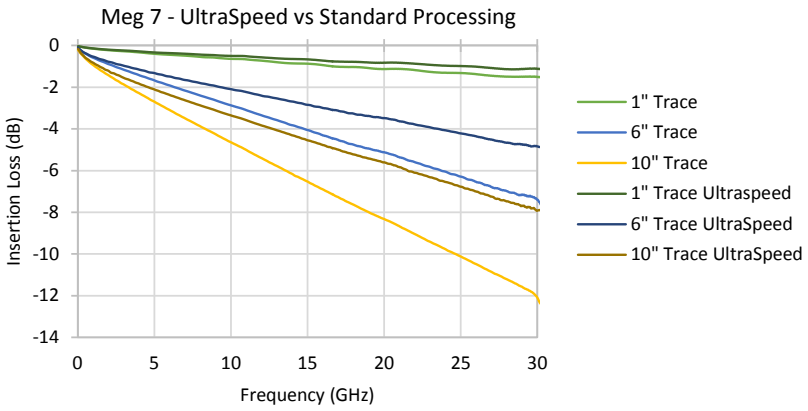
Amphenol Military & Aerospace Operations is perfectly aligned to provide the latest technologies, cost-effective manufacturing and supply chain management, and local support to solve any military and aerospace interconnect need.

AMPHENOL ULTRASPEED™

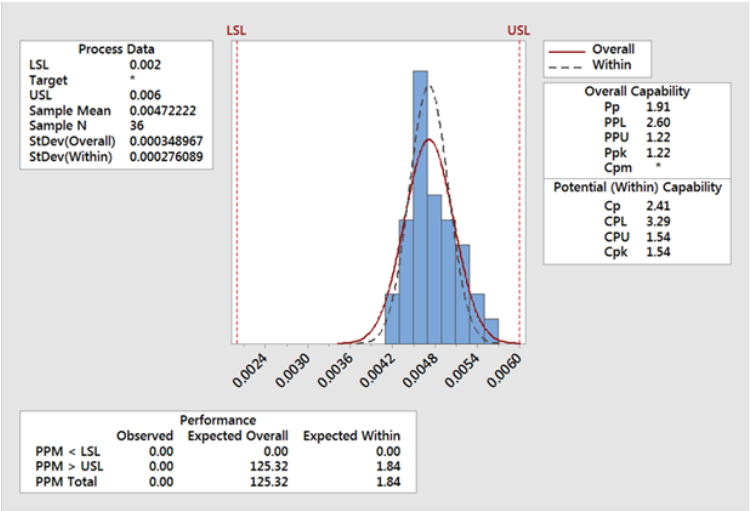
What is UltraSpeed™?

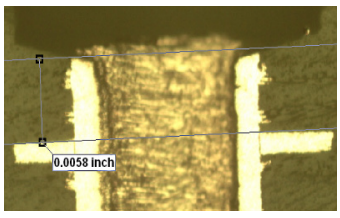
Amphenol is a leader in high speed PWB's, connectors, and assemblies working with our customers and the material suppliers to identify solutions for the ever present need for increased data rates. The raw material performance continued to improve but the gap between the required data rate and PWB performance actually widened. We evaluated the major contributors to loss on the bare boards and developed processes that provides significantly less loss than standard processing. UltraSpeed™ processing includes a patented process for controlling the topography of the conductive surfaces coupled with process development and control of other contributors including Backdrilling, Impedance Control, and Registration.

Copper Roughness
Copper roughness is impacted by copper selection and bond treatment application and the UltraSpeed™ process addresses both inputs. We have correlated the improved surface finish from UltraSpeed™ reduces the Insertion Loss by > 4 dB at 25GHz.



Back Drill Plus
Once signal speeds exceed 25 Gbps, back drilling standard via structures is required and to maintain acceptable loss levels the back drill needs to yield a stub length of .004 +/- .002. Our engineering teams have developed closed loop sensing capabilities on process equipment that couples with a unique coupon design for improved panel mapping capability to consistently provide stub lengths in the required range. This capability is critical to UltraSpeed™ performance when utilizing standard press fit contacts and is available on any size panel produced.





Cross Section Results of Plated Thru Holes After Back Drill

PCB MATERIAL CAPABILITIES

Amphenol consistently works with Material Suppliers and Customers to create and develop test vehicles that record the actual performance of materials while optimizing the process parameters to minimize signal loss and provide the optimum trace and pad geometries to deliver the best performance. Our engineering teams from both APC and SV Micro worked closely to select a high end material and optimize the launch parameters for different connector series to demonstrate the performance that Amphenol can deliver.

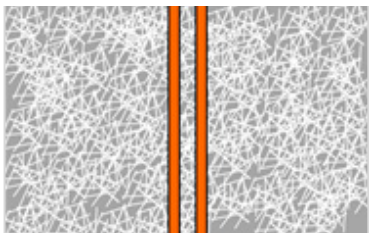
Copper Roughness
Amphenol Printed Circuits develops process guidelines and characteristics for all major types of material to support all client requests.

Laminates

- Panasonic Megtron 6, Megtron 6N, Megtron 7, Megtron 7N
- Rogers 4000 Series, 3000 Series, 6000 Series
- Rogers CLTE
- Taconic EZ Pure

Bond Ply

- Rogers 4450F, 3003, 2929, 6700
- Taconic Fast Rise

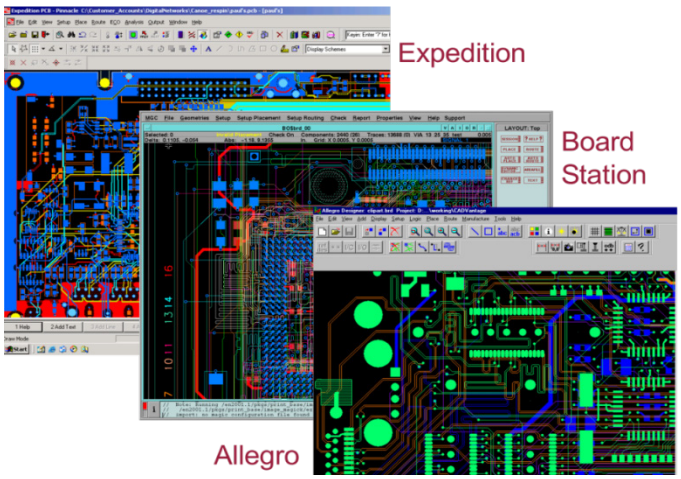


PTFE with Glass Microfiber

PTFE with Ceramic Filler

Amphenol offers a number of technical services and applications support for our product lines. These services are validated by our engineering department against our internal process guidelines and Key Characteristic Indices (KCI).

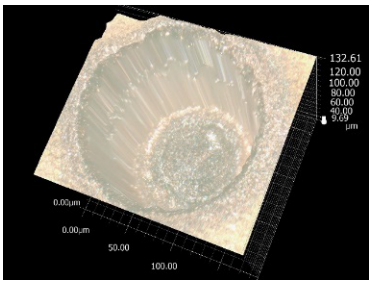
- Design / PWB Layout Services (Cadence / Mentor Graphics)
- Schematics and PWB/Assembly Drawing Packages
- Design for Manufacturability Analysis
- Impedance Modeling
- SI Modeling
- Thermal Analysis
- Feature Optimization
- Plane Layer / Power Management
- Validate Material Stack Up and Balance



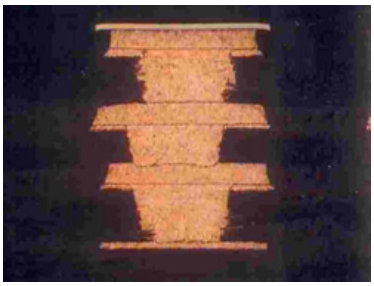
PCB MANUFACTURING CAPABILITIES

Via Structures

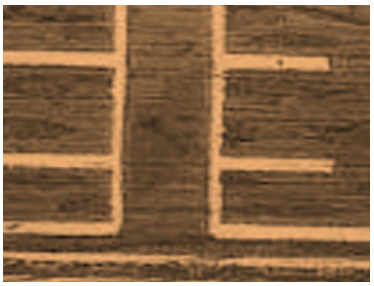
RF circuit board requirements incorporate both blind and buried via structures to successfully route traces. These HDI features place a premium on a board suppliers ability to create repeatable and reliable via structures that is only accomplished with the correct equipment set, process development, and process controls. Our Engineering Teams have developed capabilities that place us at the forefront of the market.



3D Image of a 6 mil
Microvia – Meg 6 Material



3 High Stacked Microvia Copper Filled



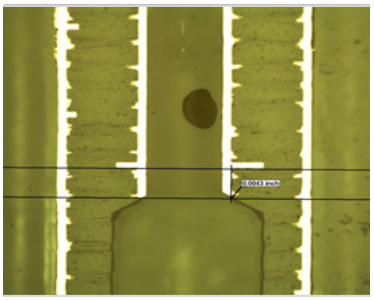
Filled Blind Microvia

Backdrill

Our precision backdrill process yields stub lengths within (1) dielectric away from live layer. This best in class performance is critical to performance at optimum data rates.

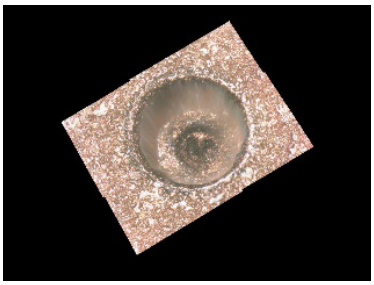
Laser Drill

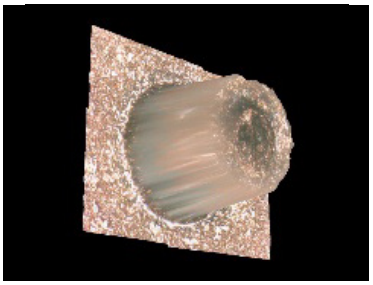
Laser drill equipment used primarily to form micro vias with the capability to go 1 to 2 layers deep. This is a dual source laser capable of processing panels 24 x 36.



Backdrilled Via

Schmoll Laser Drill

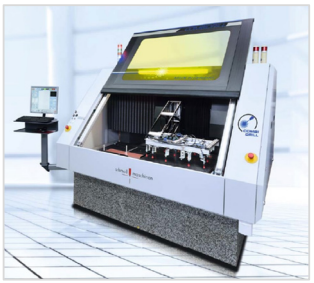




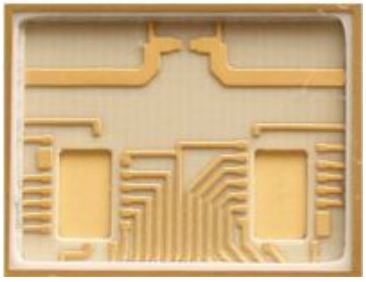
Top and Bottom Side Images on Laser Drilled Vias

PCB MANUFACTURING CAPABILITIES (CONTINUED)

Optical Router
Amphenol has invested in Optical Routing equipment to support routing cavities and other features into boards registered precisely to etched features. This equipment has the capability of providing cleanly routed features that are capable of being plated with precise location and dimension tolerances.



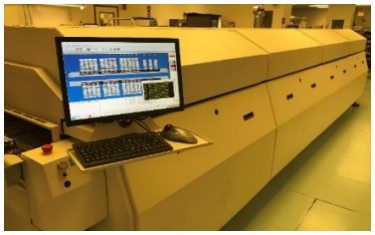
Schmoll Optical Router



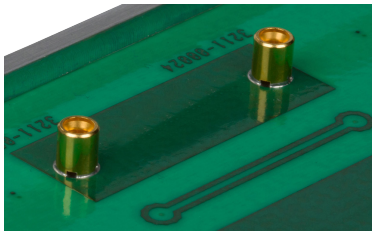
Optically Routed and Plated Cavities

Assembly Capabilities
Amphenol has the ability to perform all levels of board level assembly to provide customers with a full turnkey solution for their interconnect needs. We can assemble virtually any type of component to a PWB and excel at advanced assemblies incorporating multiple component types on a single board delivering a fully functional, tested assembly.

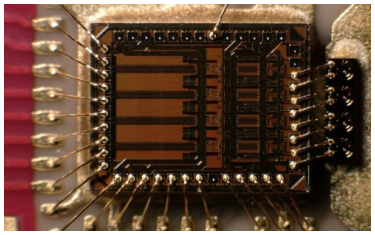
- **Fully Automated SMT /Reflow**
  We support double sided SMT with automated Solder Paste Inspection capability. Our equipment will support 42" x 48" board sizes and includes cavity paste applications and edge mounted connector soldering.
- **Wire Bond**
  Our Wire Bond process supports both gold and aluminum bonding with full X-ray capability



SMT Reflow Oven



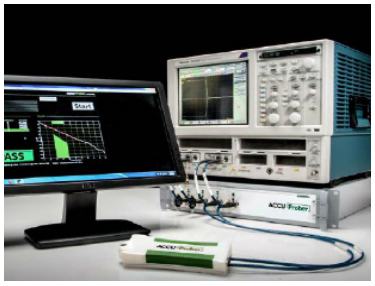
SMT/Reflow SMPM Connectors



Chip with Wire Bonding

Electrical Test
Amphenol has invested in an Introbotix ACCU Prober System that utilizes a Tektronix DSA8300 Analyzer capable of measuring Insertion / Return Loss at 50 GHz on SMA Launch and 30 GHz on Single Ended or Differential launches with a microprobe.

We recently implemented an Acculogic 12 head Flying Probe Tester for fully loaded assemblies.



Introbotix ACCU VNA Probe Test

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Stamford, CT 06902
203-327-7300

Amphenol PCD
72 Cherry Hill Drive
Beverly, MA 01915
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Amphenol SV Microwave
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561-840-1800

Amphenol Times Microwave, Inc.
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MILITARY & AEROSPACE

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